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REPORT OF THE PROCEEDINGS

OF THE

Thirty-Ninth Annual Convention

OF THE

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION

(INCORPORATED)

HELD AT

ATLANTIC CITY, N. J.,

June 18, 19 and 20, 1906.

CHICAGO:
THE HENRY O. SHEPARD COMPANY
120-130 SHERMAN STREET.
1906.

OFFICERS FOR 1906-1907.

ELECTED AT CLOSE OF CONVENTION OF 1906.

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PRESIDENT.

J. F. DEEMS, New York Central Lines, New York City.

FIRST VICE-PRESIDENT.

WM. McINTOSH, Central Railroad of New Jersey, Jersey City, N. J.

SECOND VICE-PRESIDENT.

H. H. VAUGHAN, Canadian Pacific Railway, Montreal, Canada.

THIRD VICE-PRESIDENT.

G. W. WILDIN, Erie Railroad, Meadville, Pa.

TREASURER.

ANGUS SINCLAIR, New York City.

EXECUTIVE MEMBERS.

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COMMITTEES SELECTED FOR THE 1907 CONVENTION.

1.— Mechanical Stokers:

WM. GARSTANG, Chairman,
J. F. WALSH,
GEO. S. HODGINS,
D. F. CRAWFORD.

2.— Shrinkage Allowance for Tires:

F. J. COLE, Chairman,
J. E. MUHLFELD,
W. A. NETTLETON,
D. J. DURRELL,
W. L. TRACY.

3.— Locomotive Lubrication:

D. R. MAC BAIN, Chairman,
R. F. KILPATRICK,
R. D. SMITH,
C. KYLE,
W. O. THOMPSON.

4.— Blanks for Reporting Work on Engines Undergoing Repairs:

T. H. CURTIS, Chairman,
E. W. PRATT,
C. H. QUEREAU,
F. W. LANE.

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5.— History of Movement of Locomotives at Terminals:

G. M. BASFORD, Chairman,
H. M. CARSON,
T. RUMNEY,
C. E. CHAMBERS,
J. E. MUHLFELD.

6.— Results of Use of Different Valve Gears:

C. A. SELEY, Chairman,
A. S. VOGT,
R. QUAYLE,
J. H. MANNING,
L. H. TURNER.

7.— Proper Spacing of Flues in High-pressure Boilers:

C. E. FULLER, Chairman,
H. J. SMALL,
JOHN TONGE,
F. J. COLE,
O. H. REYNOLDS.

8.— Development of Motor Cars for Light Passenger Service:

H. F. BALL, Chairman,
W. R. McKEEN, JR.
F. T. HYNDMAN,
G. W. WILDIN.
L. R. JOHNSON.

9.— The Proper Amount to Which the Gauge of Track Should Be Widened on Curves of Different Radii to Secure the Best Results with Engines Having Different Lengths of Rigid Wheel Base:

F. M. WHYTE, Chairman,
W. H. LEWIS,
F. C. CLEAVER.

10.— Subjects:

H. BARTLETT, Chairman,
J. A. CARNEY,
R. P. C. SANDERSON.

CONSTITUTION AND BY-LAWS.

ARTICLE I.

NAME.

The name of this Association shall be the "American Railway Master Mechanics' Association."

ARTICLE II.

OBJECTS OF ASSOCIATION.

The objects of this Association shall be the advancement of knowledge concerning the principles, construction, repair and service of the rolling stock of railroads, by discussions in common, the exchange of information, and investigations and reports of the experience of its members; and to provide an organization through which the members may agree upon such joint action as may be required to give the greatest efficiency to the equipment of railroads which is intrusted to their care.

ARTICLE III.

MEMBERSHIP.

SECTION 1. The following persons may become active members of the Association on being recommended by two members in good standing, signing an application for membership and agreement to conform to the requirements of the Constitution and By-Laws, or authorizing the Secretary to sign the Constitution for them:

(1) Those above the rank of general foreman, having charge of the design, construction or repair of railway rolling stock.

(2) General foremen, if their names are presented by their superior officers.

(3) Two representatives from each locomotive and car building works.

(4) One representative member may be appointed by any railroad company to represent its interests in the Association. Such appointment shall be in writing and shall emanate from the President, General Manager or General Superintendent. Such member shall have all the privileges of an active member, including one vote on all questions, and, in addition thereto, shall, on all measures pertaining to the determination of what tests shall be conducted by the Association or the expenditure of money for conducting same, have one additional vote for each full one hundred engines which are in actual operation or in process of purchase by the road or system which he represents. Such membership shall continue until notice is given the Association of his withdrawal or the appointment of his successor.

SEC. 2. Civil and mechanical engineers, or other persons having such

a knowledge of science or practical experience in matters pertaining to the construction of rolling stock as would be of special value to the Association or railroad companies, may become associate members on being recommended by three active members. The name of such candidate shall then be referred to a committee, to be appointed by the President, which shall investigate the fitness of the candidate, and report to the Executive Committee of the Association at the next annual meeting. If the report be unanimous in favor of the candidate the name shall be submitted to letter ballot, and five dissenting votes shall reject. The number of associate members shall not exceed twenty, and they shall be entitled to all the privileges of active members, excepting that of voting.

SEC. 3. (1) All members of the Association, excepting as hereafter provided, shall be subject to the payment of such annual dues as it may be necessary to assess for the purpose of defraying the expenses of the Association, provided that no assessment shall exceed $5 a year.

(2) A representative member shall pay in addition to his personal dues as above, an amount for each additional vote to which he is entitled, as shall be determined each year by the Executive Committee, prorated upon the cost of conducting such tests as may be determined upon at each convention, provided that no such assessment shall exceed $5 per vote per year.

Such dues shall be payable when the amount thereof is announced by the President, at each annual meeting. Any member who shall be two years in arrears for annual dues, shall be notified of the fact, and if the arrears are not paid within three months after such notification, his name shall be taken from the roll and he be duly notified of the same by the Secretary.

SEC. 4. Any person who has been or may be duly qualified as a member of this Association will remain such until his resignation is voluntarily tendered, or he becomes disqualified by the terms of the Constitution. Members whose names have been dropped for non-payment of dues may be restored to membership by the unanimous consent of the Executive Committee on the payment of all back dues.

SEC. 5. Members of the Association, active or associate, who have been in good standing for not less than five years, and who through age or other cause cease to be actively engaged in the mechanical department of railway service, may, upon the unanimous vote of the members present at the annual meeting, be elected honorary members. The nominations must be made by the Executive Committee. The dues of the honorary members shall be remitted, and they shall have all the privileges of active members except that of voting.

SEC. 6. Any member who, during the meetings of the Association, shall be guilty of dishonorable conduct which is disgraceful to a railroad officer and a member of the Association, or shall refuse to obey the chairman when called to order, may be expelled by a two-thirds affirmative vote at any regular meeting of the Association held within one year from the date of the offense.

ARTICLE IV.

OFFICERS.

SECTION 1. The officers of the Association shall be a President, a First Vice-President, a Second Vice-President, a Third Vice-President, a Treasurer, a Secretary, and six Executive members, the six Executive members with the President, Vice-Presidents and Treasurer shall constitute the Executive Committee, and they, with the exception of the Secretary, shall constitute the Executive Committee of the Association.

ARTICLE V.

DUTIES OF OFFICERS.

SECTION 1. It shall be the duty of the President to preside at all the meetings of the Association, appoint all committees — designating the chairman — except as hereinafter provided, and approve all bills against the Association for payment by the Treasurer.

SEC. 2. It shall be the duty of the Vice-Presidents, according to rank, to perform the duties of the President in his absence from the meetings of the Association.

SEC. 3. In case of the absence of both President and Vice-Presidents, the members present shall elect a President *pro tempore*.

SEC. 4. It shall be the duty of the Secretary to keep a full and correct record of all transactions at the meetings of the Association; to keep a record of the names and places of residence of all members, and the name of the railway they each represent; to certify to the persons who are eligible as candidates for the Association's scholarships at the Stevens Institute of Technology; to receive and keep an account of all money paid to the Association and deliver the same to the Treasurer, taking his receipt for the amount; to receive from the Treasurer all paid bills, giving him a receipted statement of the same.

SEC. 5. It shall be the duty of the Treasurer to receive all money from the Secretary belonging to the Association; to receive all bills and pay the same, after having approval of the President; to deliver all bills paid to the Secretary at the close of each meeting, taking a receipted statement of the same and to keep an accurate book account of all transactions pertaining to his office.

ARTICLE VI.

EXECUTIVE COMMITTEE.

SECTION 1. The Executive Committee shall exercise a general supervision over the interests and affairs of the Association, recommend the amount of the annual assessment, to call, to prepare for, and to conduct general conventions, and to make all necessary purchases, expenditures and contracts required to conduct the current business of the Association, but shall have no power to make the Association liable for any debt to an

amount beyond that which at the time of contracting the same shall be in the Treasurer's hands in cash, but not subject to prior liabilities. All expenditures for special purposes shall only be made by appropriations acted upon by the Association at a regular meeting.

SEC. 2. The Executive Committee shall receive, examine and approve before public reading, all communications, papers and reports on all mechanical and scientific matters; they shall decide what portion of the reports, papers and drawings shall be submitted to each convention and what portion shall be printed in the annual report.

SEC. 3. Five members of the Executive Committee shall constitute a quorum for the transaction of business.

SEC. 4. The Executive Committee shall form with a committee of the Master Car Builders' Association a Joint Committee to decide on the place of meeting for the annual convention.

ARTICLE VII.

ASSOCIATION SCHOLARSHIPS.

It shall be the duty of the Secretary to issue a circular annually, intimating the date and place when and where candidates may be examined for the scholarships of the Association in the Stevens Institute of Technology, Hoboken, New Jersey.

Acceptable candidates for the scholarship shall be, first, sons of members or of deceased members of the Association. If there is not a sufficient number of such applicants for the June examination, then applications will be received from other railroad employes or the sons of other railroad employes for the fall examination. The Secretary shall issue a proper circular in this case as before. In extending the privilege outside of the families of members, preference shall be given to employes or the sons of employes, or the sons of deceased employes of the mechanical departments.

Candidates for these scholarships shall apply to the Secretary of this Association, and if found eligible shall be given a certificate to that effect for presentation to the school authorities. This will entitle the candidate to attend the preliminary examination. If more than one candidate passes the preliminary examination, the applicant passing the highest examination shall be entitled to the scholarship, the school authorities settling the question.

The successful candidate shall be required to take the course of mechanical engineering.

ARTICLE VIII.

ELECTION OF OFFICERS.

SECTION 1. The officers of the Association, except the Secretary as hereinafter provided, shall be elected by ballot separately without nomination at the regular meeting of the Association, held in June of each year. A majority of all votes cast shall be necessary to an election, and elections

shall not be postponed. The President, Vice-Presidents and Treasurer shall hold office for one year, and Executive members for two years, or until successors are chosen, provided, however, that three Executive members shall be elected for one year at the time of the adoption of this amendment. Three Executive members shall be elected each year thereafter.

SEC. 2. Two tellers shall be appointed by the President to conduct the election and report the results.

SEC. 3. A Secretary from among the members of the Association shall be appointed by a majority of the Executive Committee at its first meeting after the annual election, or as soon thereafter as the votes of a majority of the members of the Executive Committee can be secured for a candidate. The term of office of the Secretary thus appointed, unless terminated sooner, shall cease at the first meeting, after the next annual election succeeding his appointment, of the Executive Committee organized for the transaction of business. Two-thirds of the members of the Executive Committee shall have power to remove the Secretary at any time. His compensation, if any, shall be fixed for the time that he holds office by vote of the majority of the Executive Committee. He shall also act as Secretary of the Executive Committee.

ARTICLE IX.

AUDITING COMMITTEE.

SECTION 1. At the first session of the annual meeting an Auditing Committee, consisting of three members not officers of the Association, to be nominated by any member who does not hold office, shall be elected in the same way as officers are voted for. This Auditing Committee shall examine the accounts and vouchers of the Treasurer and certify whether they have been found correct or not. After the performance of this duty they shall be discharged by the acceptance of their report by the Association.

COMMITTEE ON SUBJECTS FOR INVESTIGATION AND DISCUSSION

SEC. 2. At each annual meeting the President shall appoint a committee whose duty it shall be to report at the next annual meeting subjects for investigation and discussion, and if the subjects are approved by the Association the President, as hereinafter provided, shall appoint committees to report on them. It shall also be the duty of the committee to receive from members questions for discussion during the time set apart for that purpose. This committee shall determine whether such questions are suitable ones for discussion, and if so, they shall so report that to the Association.

COMMITTEES OF INVESTIGATION

SEC. 3. When the Committee on Subjects has reported and the Association approved of subjects for investigation, the President may appoint individuals or special committees to investigate and report on them, and may authorize and appoint a special committee to investigate and report

on any subject which a majority of the members present may approve; or individual papers may be presented to the Association after approval by the Executive Committee. Papers and reports shall be presented by abstracts, which shall not occupy more than ten minutes in the reading unless otherwise ordered by the Association.

RECOMMENDATIONS OF STANDARDS.

SEC. 4. Any proposition recommending the adoption of standard construction or practice shall be in writing and be accompanied by drawings, if the latter are necessary for a clear understanding of the subject. Such proposition shall then be submitted to the Association for discussion, after which a vote shall be taken to decide whether the proposition shall be submitted for decision by letter ballot to all the members entitled to vote. If decided in the affirmative, the Secretary, within three months from the time the vote of the Association is taken on such measure, shall send by mail to each member a blank ballot, and a copy of the proposed recommendation, with a report, to be approved by the Executive Committee, of the discussion thereon; such ballot to be filled up, signed and remailed to the Secretary, who will count all the ballots received within thirty days from the date they were sent to the members, and he shall then announce the vote in such manner as the Executive Committee may prescribe. Any recommendation securing two-thirds of the votes cast shall be adopted by the Association.

SEC. 5. All reports, resolutions and recommendations involving the use, or proposed use, by railroad companies, of any device or process which forms the subject matter of any existing patent, shall first be submitted to the Executive Committee, and shall be submitted to the Association only by the Executive Committee.

ARTICLE X.

AMENDMENTS.

SECTION 1. The Constitution may be amended at any regular meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendments has been given at a previous meeting at least six months before.

BY-LAWS.

TIME OF MEETING.

I. The regular meeting of the Association shall be held annually in June of each year.

HOURS OF SESSION.

II. The regular hours of session shall be from 9:30 o'clock A.M. to 1:30 o'clock P.M.

PLACE OF MEETING.

III. The time and place for holding the Annual Convention shall be selected by a Joint Committee composed of the President, three Vice-Presidents and Treasurer of this Association and a corresponding committee from the Master Car Builders' Association. This Joint Committee shall meet within six months after the convention and decide upon the time and place of meeting.

QUORUM.

IV. At any regular meeting of the Association, fifteen or more members entitled to vote shall constitute a quorum.

ORDER OF BUSINESS.

V. The business of the meetings of this Association shall, unless otherwise ordered by a vote, proceed in the following order:

1. Opening prayer.
2. Address by the President.
3. Acting on the minutes of the last meeting.
4. Reports of Secretary and Treasurer.
5. Assessment and announcement of annual dues.
6. Election of Auditing Committee.
7. Unfinished business.
8. New business.
9. Reports of committees.

10. Reading of papers and discussion of questions propounded by members.
11. Routine and miscellaneous business.
12. Election of officers.
13. Adjournment.

QUESTIONS FOR DISCUSSION, SPECIAL ORDER OF.

VI. Unless otherwise ordered, the discussion of questions proposed by members shall be the special order from 12 o'clock M. to 1 P.M. of each day of the annual meeting.

DECISIONS.

VII. The votes of a majority of the members shall be required to decide any question, motion or resolution which shall come before the Association, unless otherwise provided.

DISCUSSIONS.

VIII. No patentees or their agents shall be admitted in the meetings of the Association for the purpose of advocating the claims of any patent or patentee, unless by unanimous consent.

IX. No member shall speak more than twice in the discussion of any question until all the other members who want to speak, and have not been heard, have spoken, and no member shall have the floor more than five minutes at a time unless otherwise ordered.

NAMES AND ADDRESSES OF MEMBERS.

Active members are shown in Roman letters; representative members in italics.

ACTIVE MEMBERS.

ED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
5	Adams, A. B		D. F., Chicago & North-Western	Huron, S. D.
3	Adams, A. C		M. M., Chicago, Rock Island & Pacific	Trenton, Mo.
8	Adams, T. E		G. M. M., St. Louis Southwestern	Pine Bluff, Ark.
8	Addis, J. W		S. M., P. & R. S., Texas & Pacific	Marshall, Tex.
5	Aiken, C. L		Boston & Maine	South Lawrence, Mass.
3	Albright, J. S		M. M., Mexican National	San Luis Potosi, Mex.
7	Aldcorn, Thos		Chicago Pneumatic Tool Co	95 Liberty st., N.Y. City
2	Aldana, H. Lopez		S. M. P., Central Northern	Tucuman, Arg. Rep., S.A.
5	Allen, C. E		M. M., Northern Pacific	Glendive, Mont.
5	Allen, C. W		G. F., Philadelphia & Reading	Reading, Pa.
2	Allen, G. S		M. M., Philadelphia & Reading	Tamaqua, Pa.
1	Allport, Wm		G. F., Copper Range R. R	Houghton, Mich.
5	Amann, W. E		Galena Signal Oil Co	520 Rialto Building, San Francisco, Cal.
3	Anthony, F. S			148 W. Douglas st., Reading, Pa.
2	Antz, Oscar		G. L. I., New York Central Lines	Dunkirk, N. Y.
6	Appler, A. B		M. E., Delaware & Hudson Co	Green Island, N. Y.
7	*Arp, W. C*	211	*S. M. P., Vandalia*	*Terre Haute, Ind.*
5	Arthur, C. G		M. M., Southern	Columbia, S. C.
13	Ashton, Harry			401 Delaware ave., Toronto, Ont., Can.
11	Ashworth, Jas		M. M., Louisville & Nashville	Birmingham, Ala.
15	Asselin, George		P. E. M. P., Northern Ry. of France	Paris, France.
10	Atkinson, R		M. M., Philadelphia & Reading	Reading, Pa.
16	Atterbury, W. W		G. M., Pennsylvania	Philadelphia, Pa.
17	Augustus, W		M. M., Chicago, Burlington & Quincy	Centerville, Iowa.
16	Austin, W. L		Baldwin Locomotive Works	Philadelphia, Pa.
13	Ayers, H. B		American Locomotive Co	Allegheny, Pa.
16	Babcock, C. M		M. M., Texas & Pacific	McDonoghville, La.
18	Baker, C. F		S. M. P. & M., Brooklyn Rapid Transit Co.	Brooklyn, N. Y.
12	Baker, P. G		M. M., Panama	24 State st., New York. Colon (Aspinwall).
15	Balderston, J. W		M. M., Colo. & Wyoming	Sunrise, Wyo.
11	Ball, H. F		V. P., American Loco. Auto. Co	1776 Broadway, N. Y.
15	Barclay, F. B		M. M., Illinois Central	Memphis, Tenn.
16	Bardsley, A		M. M., Gulf & Ship Island	Gulfport, Miss.
14	Barnes, Chas. H			27 Cypress place, Brookline, Mass.
14	Barnes, F. P			
18	Barnes, J. B		S. L. & C. D., Wabash	Springfield, Ill.
16	Barrows, W. H		M. M., K. C. Southern	Shreveport, La.
10	Barnum, M. K		Chicago, Burlington & Quincy	Chicago, Ill.
15	*Bartlett, Henry*	1060	*S. M. P., Boston & Maine*	*Boston, Mass.*
14	Barton, T. F		M. M., Illinois Central	Burnside, Chicago, Ill.
19	Bates, F. L			2171 Howard st., Sacramento, Cal.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1905	Bather, Fred		M. F., Mexican International	Torreon, Mex.
1903	Bayley, J. J		M. M., Southern	Lawrenceville, Va.
1889	Bean, S. L		M. S., Santa Fe Lines	Los Angeles, Cal.
1892	Beattie, A. L		S. M. P., New Zealand Government	Wellington, N. Z.
1899	Beauclerk, T. S		Central Argentino	Rosario de Santa Fe, Arg. Rep., S. A.
1894	Beaumont, J. G		Southern Railways of Peru	Arequipa, Peru.
1892	Beehhold, H. G		Cleveland Frog & Crossing Co	Cleveland, Ohio.
1903	Benjamin, F. G		M. M., Chicago & North-Western	Clinton, Iowa.
1905	Bennett, Geo. R		G. F., Mobile & Ohio	Whistler, Ala.
1903	Bennett, W. J		A. S. M. P., Chgo., Indpls. & Louisville	Lafayette, Ind.
1900	Bentley, H. T		A. S. M. P. & M., Chicago & North-West	Chicago, Ill.
1906	Bentley, L. L		M. E., Lehigh Valley	South Bethlehem, Pa.
1902	Berry, Arthur O		G. F. L. D., Lake Shore & Mich. South	Collinwood, Ohio.
1900	Best, W. N			11 Broadway, New York.
1892	Billingham, Jos			
1903	Billingham, R. A		G. M. M., Pitts., Shawmut & Northern	St. Marys, Pa.
1902	Bingaman, Chas. A		Care of S. M. P., Phila. & Reading	Reading, Pa.
1899	Bissett, J. R		M. M., Seaboard Air Line	Raleigh, N. C.
1901	Blake, R. P		A. S. S., Northern Pacific	Brainerd, Minn.
1904	Bock, M. G		S. M. P. & R. S., De Queen & Eastern	De Queen, Ark.
1899	Boldridge, R. M		M. M., Miss. Central	Hattiesburg, Miss.
1904	Boler, W. L		M. M., Del., Lack. & Western	Kingsland, N. J.
1904	Booth, J. S		M. M., Caro. & Northwestern	Chester, S. C.
1904	Booth, Thos		M. S., Pecos Valley Lines	Amarillo, Tex.
1897	Bowles, C. K			
1895	Bradeen, J. O		M. M., N. Y. Cent. & Hudson River	New Durham, N. J.
1888	Bradley, W. F		Supt., Ann Arbor	Owosso, Mich.
1904	Brady, T. F		S. M., Mapini	Mapini, Durango, Mex.
1894	Branch, Geo. E			292 Prospect place, Brooklyn, N. Y.
1896	Brangs, P. H			11 Broadway, N. Y. City.
1900	Brassell, J. K		M. M., Cal. Northwestern	Tiburon, Cal.
1904	Braun, C. A		M. M., Mo. Pacific	Osawatomie, Kan.
1902	Brazier, F. W		S. R. S., N. Y. Cent. & Hudson River	New York City.
1892	Brehm, W. H		M. M., Mo. Kan. & Tex	Parsons, Kan.
1904	Breneman, H. N		A. S. M. P., Chicago, Mil. & St. Paul	West Milwaukee, Wis.
1897	Briggs, D. D		M. M., Louisville & Nashville	Anniston, Ala.
1879	Briggs, R. H		M. M., St. Louis & San Francisco	Memphis, Tenn.
1898	*Bronner, E. D*	479	*S. M. P., Michigan Central*	*Detroit, Mich.*
1887	Brooke, Geo. D		Panama Canal Commission	Ancon, Canal Zone.
1892	Brown, David		A. S. M. P., Del., Lack. & Western	Scranton, Pa.
1905	Brown, H. B		M. M., Erie	Cleveland, Ohio.
1896	Brown, M. D		Mo., Kan. & Texas	New Franklin, Mo.
1891	Brown, W. A		M. M., Kanawha & Michigan	Middleport, Ohio.
1904	Brown, T. A		S. M. P., Louisiana & Arkansas	Stamps, Ark.
1895	Browne, T. R		Engr., American Car & Foundry Co	25 Broad st., New York
1882	Brownell, F. G			Muncie st., Muncie, Ind.
1897	Bruce, Geo. A		G. M. M., Great Northern	St. Paul, Minn.
1890	Bruck, Henry T		M. of M., Cumb. & Penna	Mt. Savage, Md.
1882	Bryan, H. S		S. M. P., Duluth & Iron Range	Two Harbors, Minn.
1906	Bryant, E. G		D. M. M., International & Great North	Mart, Tex.
1900	Buchanan, A., Jr		S. M. P., Central Vermont	St. Albans, Vt.
1902	Buchanan, Jas			25 Thames st., N.Y. City.
1887	Buchanan, Wm			26 Fairfield ave., So. Norwalk, Conn.
1906	Burel, W. C		M. M., Trinity & Brazos Valley	Cleburne, Tex.
1905	Burgis, E. W		M. M., N. O., Ft. Jackson & Grand Isle	Algiers, La.
1905	Burkheimer, H. W		M. M., Louisville & Nashville	Louisville, Ky.
1893	Bush, S. P		Buckeye Steel Castings Co	Columbus, Ohio.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
190[illegible]	Bushmeyer, C. J			Judsonia, Ark.
1906	Bussing, G. H		S. M. P. & R. S., Evans. & Terre Haute	Evansville, Ind.
1893	*Butcher, Geo.W*	59	*S. M. P., San Antonio & A. Pass*	*San Antonio, Tex.*
1904	Cameron, J. E		M. M., Atlantic & Birmingham	Waycross, Ga.
1903	Campbell, A. A		M. M., Kansas City Southern	Shreveport, La.
1896	Cannon, T. E		M. M., Great Northern	Melrose, Minn.
1905	Cardell, J		M. M , Canadian Pacific	Calgary, Alberta, Can.
1902	Caracristi, V. Z		American Locomotive Co	Richmond, Va.
1904	Cargo, B. B		M. M., Lake Terminal	Lorain, Ohio.
1900	Carney, J. A		S. S., Chicago, Burlington & Quincy	West Burlington, Iowa.
1903	Carson, F. L		M. M., El Paso & Northeastern	Alamogordo, N. M.
1889	Casanave, F. D			1710 Market st., Philadelphia, Pa.
1890	Casey, J. J		Supt., American Car & Foundry Co	Jeffersonville, Ind.
1904	Cassidy, D. E		M. M., Pennsylvania	Allegheny, Pa.
1892	Chamberlin, E			610 Grand Central Depot, New York City.
1903	Chambers, C. E		M. M., Central R. R. of N. J	Jersey City, N. J.
1893	Chambers, John S		S. M. P., Atlantic Coast Line	Wilmington, N. C.
1901	Chase, C. F		American Locomotive Co	Manchester, N. H.
1896	Chase, F. A		G. M. I., Chicago, Burlington & Quincy	St. Joseph, Mo.
1904	*Chester, W. E*	257	*G. M. M., Central of Georgia*	*Savannah, Ga.*
1905	Chidley, Joseph		Lake Shore & Mich. Southern	Elkhart, Ind.
1906	Chisholm, J. E		G. M. M., Chicago Great Western	Oelwein, Iowa.
1898	Christopher, J		M. M., Toronto, Hamilton & Buffalo	Hamilton, Ont., Can.
1902	Churchward, G. J		Great Western	Swindon, England.
1905	Clark, David		M. M., Arizona & New Mexico	Clifton, Ariz.
1899	*Clark, F. H*	1346	*G. S. M. P., Chgo., Burl. & Quincy*	*Chicago, Ill.*
1886	Clark, Isaac W			Fayetteville, N. C.
1903	Clark, J. H		M. M., Staten Island R. T	Clifton, S. I., New York.
1897	Clarke, Owen		M. M., Texas & Pacific	Marshall, Texas.
1903	Clarkson, W. S		G. M. M., Northern Pacific	Livingston, Mont.
1901	Clay, S. B			1220 N. 6th st., Ft. Smith, Ark.
1893	Cleaver, F. C		S. M. P., Rutland	Rutland, Vt.
1877	Clifford, J. G			10th and Kentucky sts., Louisville, Ky.
1887	Cloud, John W			82 York Road, King's Cross, London, Eng.
1903	Cockfield, William		L. & C. S., Mexican	Orizaba, Mexico.
1896	Cole, F. J		American Locomotive Co	111 Broadway, New York City.
1904	Cole, T. J		M. M., Erie	Meadville, Pa.
1905	Collin, George		Northern Ry. of France	Paris, France.
1906	Collins, W. H		M. M., Fonda, Johnstown & Gloversville	Gloversville, N. Y.
1906	Conners, J. J		M. M., Chicago, Milwaukee & St. Paul	Dubuque, Iowa.
1890	*Conolly, J. J*	93	*S. M. P., Dul., So. Shore & Atlantic*	*Marquette, Mich.*
1879	Cook, John S		M. M., Georgia	Augusta, Ga.
1904	Cooper, F. R		M. M., Lehigh Valley	Buffalo, N. Y.
1902	Cota, A. J		M. M., Chicago, Burlington & Quincy	Chicago, Ill.
1904	Coutant, M. R		M. M., Ulster & Delaware	Rondout, N. Y.
1905	Coyle, Thomas		M. M., Lehigh Valley	Weatherly, Pa.
1900	Crawford, D. F		G. S. M. P., Pennsylvania Lines	Pittsburgh, Pa.
1904	Cromwell, O. C		M. E., Baltimore & Ohio	Baltimore, Md.
1902	Cross, C. W		M. M., Lake Shore & Mich. Southern	Elkhart, Ind.
1902	Cross, J. W		Great Western Ry	Swindon, England.
1893	*Cross, W*	504	*Asst. to 2d V. P., Canadian Pacific*	*Winnipeg, Man., Can.*
1899	Cumback, R. O			Plainfield, N. J.
1906	Cunningham, D. W		M. M., Chicago, Rock Island & Pacific	Valley Junction, Iowa.
1900	Curley, M. S		S. M. P., Sierra Ry. of Cal	Jamestown, Cal.
1903	Curry, H. M		G. M. M., Northern Pacific	St. Paul, Minn.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1903	Curtis, Theo. H		S. M., Louisville & Nashville	Louisville, Ky.
1904	Cutler, T. J		M. M., Northern Pacific	Missoula, Mont.
1899	Davis, Chas. H		Barclay	25 Broad st., New York City.
1906	Davis, David E		M. M., Boston & Maine	Concord, N. H.
1892	Davis, Ed. E		Buffalo, Rochester & Pittsburg	Dubois, Pa.
1899	Davis, M. R		M. M., Portland & Rumford Falls	Rumford Falls, Me.
1900	Davisson, F. E		S. M., San Pedro, Los Ang. & Salt Lake	Los Angeles, Cal.
1897	Dawson, E		M. M., Gila Valley, Globe & Northern	Globe, Ariz.
1903	Dawson, L. L		M. M., Illinois Central	McComb, Miss.
1896	Deeble, Wm. R		Tasmania Government	Launceston, Tasmania.
1891	*Deems, J. F*	2881	*G. S. M. P., New York Central Lines*	*New York City.*
1905	Deeter, D. H		M. M., Philadelphia & Reading	Reading, Pa.
1896	De Gress, C		Mex. National Construction Co	Colima, Mex.
1897	Delaney, C. A		American Locomotive Co	Scranton, Pa.
1895	Delaney, H			14 Stuyvesant Place, Staten Island, N. Y.
1905	Delaney, S. J		M. M., N. Y. C. & H. R. R. R	New York City.
1899	Delano, F. A		Prest., Wabash	Chicago, Ill.
1900	Demarest, T. W		S. M. P., Pennsylvania Lines	Ft. Wayne, Ind.
1905	Desmond, D. G		M. M., Morgantown & Kingwood	Morgantown, W. Va.
1903	Deverell, A. C		A. S. M. P., Great Northern	St. Paul, Minn.
1905	Dewey, J. J		M. M., Erie	Galion, Ohio.
1896	Dickerson, S. K		A. S. M. P., Lake Shore & Mich. Sou	Cleveland, Ohio.
1887	Dickson, G. L		American Locomotive Co	Scranton, Pa.
1902	Dickson, Geo		M. M., Chicago, Cincinnati & Louisville	Peru, Ind.
1905	Dickson, John		M. M., Great Northern	Grand Forks, N. D.
1900	Dillon, S. J		M. M., Pennsylvania	South Amboy, N. J.
1905	Dinan, Arthur		M. M., Atchison, Topeka & Santa Fe	Newton, Kan.
1905	Dinkel, M. C		S. M. P. & M., Ixt., Mani & Nijini Ry	Ixtlahuaca, Mex.
1894	Dixon, W. F			Podolsk, Moscow, Govt., Russia.
1897	Doebler, C. H			Ft. Wayne, Ind.
1905	Dolan, J. P		M. M., St. Louis & No. Arkansas	Eureka Springs, Ark.
1898	Dolan, S. M		M. M., Missouri Pacific	Sedalia, Mo.
1904	Dooley, W. H		M. M., Cin., New Orleans & Tex. Pac	Chattanooga, Tenn.
1903	Doonan, W. F		M, M., Great Northern	Whitefish, Mont.
1893	Dow, Jas. M			Kenton, Ohio.
1899	Downing, T. M		M. M., Virginia & Carolina Coast	Suffolk, Va.
1904	Driscoll, J. L		M. M., Alabama Great Southern	Birmingham, Ala.
1893	Drury, Michael J		M. M., Atchison, Topeka & Santa Fe	Winslow, Ariz.
1904	Dunham, W. E		M. M., Chicago & North-Western	Winona, Minn.
1903	Dunlap, P. T		M. M., Gulf, Colorado & Santa Fe	Temple, Tex.
1900	*Dunn, A. J*	20	*M. M., Virginia & Southwestern*	*Bristol, Va.*
1896	*Dunn, J. F*	190	*S. M. P., Oregon Short Line*	*Salt Lake City, Utah.*
1904	Durborow, R. N		S. M. P., Pennsylvania	Altoona, Pa.
1906	Durham, H. P		S. M. P., Tehuantepec National	Rincon, Ant., Oaxaca, Mex.
1906	Durrell, D. J		A. S. M. P., Pennsylvania Lines	Columbus, Ohio.
1906	Edmonds, G. S		M. M., Delaware & Hudson Co	Oneonta, N. Y.
1905	Edmondson, W. G		E. of T., Philadelphia & Reading	Reading, Pa.
1899	Egan, J. A		G. F., Mexican Southern	Oaxaca, Mex.
1900	Elden, Edw		M. M., N. Y. C. & H. R	East Buffalo, N. Y.
1869	Elliott, Henry		Elliott Frog & Switch Co	East St. Louis, Ill.
1906	Elliott, J. B		G. M. M., Canadian Pacific	Montreal, Can.
1899	Ellis, H. D		Anglo-Chilian Nitrate & Railway Co	Tocapilla, Chili.
1893	Ellis, John J		S. M. P. & M., C. St. P. M. & O	St. Paul, Minn.
1906	Elordi, Manuel		Gen. Insp., Argentine Govt. Ry	New York City.
1901	Emerson, G. H		S. M. P., Great Northern	St. Paul, Minn.

ED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
5	Emerson, H		Con. Eng., Atch., Topeka & Santa Fe	Topeka, Kan.
3	English, H. W			Birmingham, Ala.
3	English, Richard		1917 Mission st.,	San Francisco, Cal.
1	Ennis, W. C		M. M., Delaware & Hudson Co	Carbondale, Pa.
5	Enright, J. F		M. M., Mobile & Ohio	Whistler, Ala.
8	Ettinger, R. L		C. M. E., Southern	Washington, D. C.
0	Ewing, J. J		M. E., Chesapeake & Ohio	Richmond, Va.
4	Farrell, R. J			Sparta, Ill.
0	*Feeley, T. M*	88	*M. M., Iowa Central*	*Marshalltown, Iowa.*
5	Ferguson, G. A		Boston & Albany R. R	So. Station, Boston, Mass.
5	Ferguson, L. B		M. M., Vicksburg, Shreveport & Pac	Monroe, La.
4	Ferguson, T. G		Cordova & Rosario	Rosario, Arg. Rep., S. A.
4	Fetner, W. H		M. M., Central of Georgia	Macon, Ga.
3	Fildes, J. H		M. M., Lehigh Valley	E. Buffalo, N. Y.
1	Fildes, Thos			Richmond Hill, L. I., N. Y.
5	Fitzgerald, W. T		M. M., Wisconsin & Michigan	Peshtigo, Wis.
2	Fitzmorris, Jas		M. M., Chicago Junction	Un. Stk. Yds., Chicago, Ill.
5	Flavin, J. T		M. M., Ind., Ill. & Southern	Kankakee, Ill.
3	Fleischer, J. F		M. M., Chicago & North-Western	Sioux City, Iowa.
3	Flory, B. P		M. E., Central of New Jersey	Jersey City, N. J.
1	*Fogg, J. W*	39	*M. M., Chicago Terminal Transfer*	*East Chicago, Ind.*
6	*Foque, T. A*	155	*M. S., M. St. Paul & S. Ste. M*	*Minneapolis, Minn.*
5	Ford, Daniel W		M. M., Pacific Coast	San Luis Obispo, Cal.
5	Forster, John		M. M., St. Louis & San Francisco	Kansas City, Mo.
0	Forsyth, A		S. S., Chicago, Burlington & Quincy	Aurora, Ill.
8	Forsyth, Wm		M. E., *The Railway Age*	Chicago, Ill.
4	Foster, W. T		M. M., Tennessee Copper Co.'s Ry	Copperhill, Tenn.
7	Fowle, I. W			Riverside, Cal.
6	Franey, M. D		S. S., Lake Shore & Mich. Southern	Collinwood, Ohio.
6	Friere, de Silva, J. G		L. S., Central Ry. of Brazil	Rio de Janeiro, Brazil, S. A.
1	French, R. E.		Southern Pacific	Oakland, Cal.
8	Frey, N		M. M., Chicago, Burlington & Quincy	La Crosse, Wis.
4	Fries, A. J		M. M., Boston & Albany	Allston, Mass.
3	Fryburg, F. M		M. M., Great Northern	Havre, Mont.
0	*Fuller, C. E*	234	*S. M. P., Chicago & Alton*	*Bloomington, Ill.*
2	Fuller, Wm			213 Kennard st., Cleveland, Ohio.
7	Gaines, F. F		M. M., Philadelphia & Reading	Reading, Pa.
4	Gairns, A. H		M. M., Colorado & Southern	Cheyenne, Wyo.
1	Galbraith, R. M			Pine Bluff, Ark.
1	Gallagher, G. A		M. M., Ill. Southern	Sparta, Ill.
4	Galloway, W. S		Baltimore & Ohio	Camden Station, Baltimore, Md.
4	Gannon, J. B		M. M., Central New England	Hartford, Conn.
7	Garstang, Wm		S. M. P., C. C. C. & St. L	Indianapolis, Ind.
0	Gaskins, W. B		M. M., St. Louis & San Francisco	Cape Girardeau, Mo.
3	Gauthier, Jesse		M. M., Copper Range	Houghton, Mich.
6	Gentry, T. W		American Locomotive Co	Richmond, Va.
5	George, Wm. E		Western Australian Rys	Perth, Australia.
9	Gibb, T. M		G. S., Crystal River	Redstone, Colo.
8	Gibbs, A. W		G. S. M. P., Pennsylvania	Altoona, Pa.
0	Gibbs, George			10 Bridge st., New York.
2	Gibson, J. A		M. M., C. C. C. & St. L	Urbana, Ill.
4	Gilbert, E. B		S. M. P., Bessemer & Lake Erie	Greenville, Pa.
5	Gilbert, F. M		M. E., N. Y. C. & H. R. R. R	G. C. Sta., N. Y. City.
6	Gill, John		S. M. P., Chicago, Indplis. & Louisville	Lafayette, Ind.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1905	Gillett, L. D		M. M., Norfolk & Western	Bluefield, W. Va.
1891	Gillis, H. A		Auto-Car Co	Ardmore, Pa.
1905	Gilman, G. H		S. S., Northern Pacific	St. Paul, Minn.
1883	Gilmore, W. L			Elkhart, Ind.
1893	Gilmour, George		Travelers' Insurance Co	Hartford, Conn.
1890	Givin, F. A			797 N. 38th st., Philadelphia, Pa.
1891	Glass, John C		M. M., Pennsylvania	Verona, Pa.
1905	Goodale, R. J		M. M., Illinois Central	Centralia, Ill.
1904	Goodman, J. E		M. M., Northern Pacific	Duluth, Minn.
1905	Goodrich, Max		M. M., New York & Ottawa	Ottawa, Ont., Can.
1880	Gordon, H. D			71 John st., New York.
1906	Gossett, C. E		M. M., Chicago, Rock Island & Pacific	Eldon, Mo.
1900	Gould, J. E		S. M. P., Norfolk & Southern	Norfolk, Va.
1904	Gould, J. R		M. M., Chesapeake & Ohio	Richmond, Va.
1899	Gould, R		Buenos Ayres Great Southern	Buenos Ayres, Arg. Rep., S. A.
1892	Graham, Charles		M. M., Philadelphia & Reading	Reading, Pa.
1894	Graham, J. A			Wyoming, Ohio.
1903	Graham, S. C		M. M., Chicago & North-Western	Lake City, Iowa.
1903	Grandy, W. S		M. M., Atchison, Topeka & Santa Fe	Newton, Kan.
1894	Grant, A. S		M. M., Missouri Pacific	De Soto, Mo.
1906	Gray, B. H		M. M., New Orleans Terminal	New Orleans, La.
1906	Gray, G. M		M. E., Bessemer & Lake Erie	Greenville, Pa.
1889	Greatsinger, J. L		Brooklyn Rapid Transit	Brooklyn, N. Y.
1897	Greaven, Luis		S. M. P., Buenos Ayres Gt. Sou.	Buenos Ayres, Arg. Rep. S. A.
1906	Greard, Henry Octave		A. S. M. P., French State Rys	Paris, France.
1905	Green, H		M. E., So. Balto. Steel Car & Fdy. Co	Baltimore, Md.
1895	Green, Wilbur		M. M., San Antonio & Aransas Pass	Yoakum, Tex.
1905	Greenwood, B. E		G. F., Seaboard Air Line Ry	Portsmouth, Va.
1885	Griffith, Fred B			797 Elmwood ave., Buffalo, N. Y.
1893	Gross, R. J		American Locomotive Co	New York.
1896	Groves, J. R		S. M. P., Denver & Rio Grande	Denver, Colo.
1900	Gurry, Geo		G. S., Locomotive & Machine Co.	Montreal, Can.
1906	Guthbrod, F. W		Prussian State Rys	Berlin, Germany.
1893	Hainen, J		G. M. M., Southern	Greensboro, N. C.
1898	*Hair, John*	194	*S. M. P., Balto. & Ohio S.-W*	*Cincinnati, Ohio.*
1906	Hale, H. H		A. M. M., Pere Marquette	Grand Rapids, Mich.
1904	Hall, Chas. S		M. M., Boston & Maine	Springfield, Mass.
1904	Hall, Grant		A. S. M. P., Canadian Pacific	Montreal, Can.
1902	*Hammett, P. M*	167	*S. M. P., Maine Central*	*Portland, Me.*
1905	Hammond, G. O		M. E., Erie	Meadville, Pa.
1891	Hancock, Geo. A		S. M. P., St. Louis & San Francisco	Springfield, Mo.
1893	Hancock, Wm. S			3654 Olive st., St. Louis, Mo.
1893	Hardie, Jas			Hardie & Co., Valparaiso, Chili.
1905	Harkon, J. W		G. S., Canada Foundry Co	Toronto, Can.
1906	Harrigan, P. J		M. M., Baltimore & Ohio	Connellsville, Pa.
1906	Harrington, H. H		M. M., Erie	Susquehanna, Pa.
1902	Harris, J. D		Westinghouse Air Brake Co	Wilmerding, Pa.
1898	Harrison, F. J		M. M., Buffalo, Rochester & Pittsburg	Du Bois, Pa.
1896	Harrison, John		San Paulo	San Paulo, Brazil, S. A.
1904	Harrison, W. L		A. S. M. P., Chicago, Rock Island & Pac	Chicago, Ill.
1903	Hartigan, B		G. F., Rutland	Rutland, Vt.
1901	Haselton, G. H		S. M. P., N. Y. C. & H. R. R. R	West Albany, N. Y.
1889	Haskell, B			Franklin, Pa.
1888	Hassman, Wm		M. M., Peoria & Pekin Union	Peoria, Ill.
1905	Hatz, G. K		M. M., Chicago & Alton	Bloomington, Ill.
1900	Hawkins, B. H		M. M., Del., Lack. & Western	Buffalo, N. Y.

NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
ɪwkins, R. D		G. M. M., Great Northern	Minot, N. D.
ɪwksworth, D		Chicago, Burlington & Quincy	Plattsmouth, Neb.
ɪwthorne, J			Susquehanna, Pa.
ɪyes, J. T		M. M., Grand Rapids & Indiana	Grand Rapids, Mich.
ɪyes, W. C		Supt., Erie	Susquehanna, Pa.
ɪynen, W. J		M. M., Detroit, Toledo & Ironton	Jackson, Ohio.
ɪyward, H. S		S. M. P., Pennsylvania	Jersey City, N. J.
ɜdley, F		G. M., Interborough R. T. Ry. Co	New York City.
ɜintzleman, T. W		S. M. P., Southern Pacific	Sacramento, Cal.
ɜnderson, G. R			20 W. 34th st., New York.
ɜrr, Edwin M			Edgewood Park, Pa.
ɜrr, H. T			Duquesne, Ariz.
bbard, H. Wade		Cornell University	Ithaca, N. Y.
ckey, F. P		M. M., Seaboard Air Line	Raleigh, N. C.
ckey, Maurice		M. M., Northern Pacific	Spokane, Wash.
ckey, P. J		M. M., C. C. C. & St. L	Mattoon, Ill.
cks, I. C		M. M., Santa Fe Lines	Albuquerque, N. M.
ggins, S		G. M., N. Y., New Haven & Hartford	New Haven, Conn.
ldreth, F. F		M. M., Vandalia	Terre Haute, Ind.
lferty, C. D		Cooke Locomotive Works	Paterson, N. J.
ll, Jas. W			Peoria, Ill.
ll, Rufus		M. M., Pennsylvania	Pavonia, N. J.
ll, W. H		M. M., Cornwall	Lebanon, Pa.
llman, C. R		A. S. M. P., San Paulo	San Paulo, Brazil, S. A.
ɔbson, W. P		A. M. M., Chesapeake & Ohio	Lexington, Ky.
ɔffman, C. M		M. M., Southern	Princeton, Ind.
ɔffman, R. F			10 Bloom st., Danville, Pa.
ɔgan, C. H		M. M., N. Y. C. & H. R. R. R	Depew, N. Y.
ɔlland, W. D		Southern Pacific	Los Angeles, Cal.
ɔltz, D		Western Maryland	Union Bridge, Md.
ɔmer, John C		A. M. M., Cin., Hamilton & Dayton	Indianapolis, Ind.
ɔpwood, John		Argentine Great Western	Mendoza, Argentine Rep., S. A.
ɜrrigan, John	138	*S. M. P., E. J. & E., C. L. S. & E. Rys*	*Joliet, Ill.*
ɪrsey, A. W		M. E., Can. Pacific	Montreal, Can.
ɪward, C. H			504 Columbia Bldg., St. Louis, Mo.
ɪward, John		S. M. P., Boston & Albany	Boston, Mass.
ɔwe, H. B		New South Wales Rys	Sydney, Australia.
ɪwson, G. N		M. M., Southern	Birmingham, Ala.
ɪbe, A. A		M. M., New Orleans & North Western	Thornton, Ark.
ɪfman, W. H		M. M., Chicago & North-Western	Baraboo, Wis.
ɪdson, H. G			1436 84th st., Cleveland, Ohio.
ɪdson, W. H		G. M. M., Southern	Birmingham, Ala.
ɪfsmith, F			Palestine, Tex.
ɪme, E. S		C. M. E., Western Australian Govt. Rys	Freemantle, Australia.
ɪmphrey, A. L		G. M., Westinghouse Air Brake Co	Pittsburgh, Pa.
ɪngerford, S. J		S. L. Wks., Can. Pacific	Winnipeg, Man.
ɪnt, H. B		American Locomotive Co	Schenectady, N. Y.
ɪnter, H. S		M. M., Philadelphia & Reading	Philadelphia, Pa.
ɜndman, F. T.	1192	*M. S., N. Y., New Haven & Hartford*	*New Haven, Conn.*
ge, T. S		S. M. P., Danville & Western	Danville, Va.
ɾin, J. E		M. M., Marietta, Columbus & Cleveland	Marietta, Ohio.
nes, E. T		M. M., Lehigh Valley	Sayre, Pa.
nes, Geo		M. M., N. Y. C. & St. L	Sta. S, Chicago, Ill.
ɔiot, Marcel		A. S. M. P., French State Rys	Dijon, France.
ɪnings, Thos		M. M., Boston & Maine	Keene, N. H.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1890	Jennings, Wm		Pacific Electric Ry	Los Angeles, Cal.
1896	Johnson, A. B		Baldwin Locomotive Works	Philadelphia, Pa.
1902	Johnson, Ben		S. M., Mexican Central	City of Mexico.
1887	Johnson, L. R		S. M. P., Canadian Pacific	Montreal, Can.
1903	Johnson, R. A		M. M., Southern Pacific	Sonora, Mex.
1903	Johnson, W. O		627 Ry. Exchange Bldg.,	Chicago, Ill.
1905	Jones, C. F		M. M., Natchez, Urania & Ruston	Urania, La.
1888	Joughins, G. R		M. S., Intercolonial	Moncton, N. B., Can.
1903	Jungling, M		318 Read st.,	Kingwood, Ga.
1896	Justice, D. J		722 W. Chestnut st.,	Louisville, Ky.
1905	Kaderly, W. F		M. M., Southern	Alexandria, Va.
1890	Kalbaugh, I. N		S. M. P., W. Va., Cent. & Pittsburg	Union Bridge, Md.
1903	*Kapp, W. F*	51	*S. S. & M., Rich., Fred. & Potomac*	*Richmond, Va.*
1904	Kearney, Alex		A. S. M. P., Norfolk & Western	Roanoke, Va.
1892	*Keegan, Jas. E*	92	*S. M. P., Grand Rapids & Indiana*	*Grand Rapids, Mich.*
1904	Kellogg, W. L		M. M., Pere Marquette	Grand Rapids, Mich.
1896	Kells, Willard		M. M., Lehigh Valley	Sayre, Pa.
1896	Kelly, Wm		G. M. M., Great Northern	Spokane, Wash.
1905	Kendall, H. H		M. M., St. L., Brownsville & Mexico	Kingsville, Tex.
1904	Kendig, R. B		M. E., Lake Shore & Mich. Southern	Cleveland, Ohio.
1894	Kennedy, Jas		158 Prospect st.,	Cambridge, Mass.
1893	Kenney, Geo. W		M. M., Rutland	Rutland, Vt.
1901	Keyworth, T. E		Cuban Central Rys., Ltd	Sagua La Grande, Cuba.
1904	Kidd, L. M		M. M., Mex. International	Monclava, Mex.
1890	Killen, W. E			Jacksonville, Ill.
1903	Kilpatrick, J. B		A. S. M. P., Chicago, R. I. & Pacific	Chicago, Ill.
1900	Kilpatrick, R. F		S. M. P., Del., Lack. & Western	Scranton, Pa.
1903	Kinnaird, L. S		M. M., Cleveland, Akron & Columbus	Mt. Vernon, Ohio.
1905	Kinney, W. H		M. M., New York, Ont. & Western	Mayfield, Pa.
1902	Kipp, A. R		M. M., Wisconsin Central	Fond du Lac, Wis.
1904	Kirkpatrick, Jas		M. M., Baltimore & Ohio	Cumberland, Md.
1902	Knight, Wm. Edw		G. M. M., United Rys. of Havana	Havana, Cuba.
1902	Krauss, J. I		M. M., K. C. Southern	Mena, Ark.
1905	Kyle, C		M. M., Canadian Pacific	Montreal, Can.
1899	Lachlan, Wm		E. de F. Porto Alegre & New Hamburg,	Porto Alegre, Rio Grande do Sul, Brasil.
1898	Lake, E. M		Camp & Hinton Co	Lumberton, Miss.
1888	Lape, C. F		Scully Steel & Iron Co	Chicago, Ill.
1905	Laurent, Theo		A. C. E., Paris & Orleans Ry	Paris, France.
1891	Lawes, T. A		M. E., New York, Chicago & St. L	Cleveland, Ohio.
1896	Lawrence, J. L		G. F. S., Cumberland Valley	Chambersburg, Pa.
1890	Leach, H. L		A. S. M. P., Bangor & Aroostook	Houlton, Me.
1903	Leach, W. B		383 Dorchester ave.,	South Boston, Mass.
1892	Lee, C. W			Greensboro, N. C.
1904	Leeman, W. W			Goodland, Kan.
1888	Leigh, F. J		30 Kenilworth Road,	Ealing, London, W., Eng.
1890	Leonard, A. G		Union Stock Yards	Chicago, Ill.
1876	*Lewis, W. H*	697	*S. M. P., Norfolk & Western*	*Roanoke, Va.*
1904	Link, T. C		M. M., Cananea Cons. Copper Co	Cananea, Sonora, Mex.
1896	Linstrom, Chas		M. M., Illinois Central	Vicksburg, Miss.
1903	Litton, Francis H		Shansi Honan Ry	Chiaotso, Honan, China.
1890	*Lloyd, T. S*	1287	*G. S. M. P., Chicago, R. I. & Pacific*	*Chicago, Ill.*
1905	Lockwood, B. D		M. E., Clev., Cin., Chicago & St. L	Indianapolis, Ind.
1895	Lonergan, P. T		M. M., Boston & Albany	W. Springfield, Mass.

NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
ovell, Alfred		S. M., Atchison, Topeka & Santa Fe	Chicago, Ill.
yddon, H. A		Northern Pacific	Gladstone, Minn.
ynn, M. J		M. M., Buffalo, Roch. & Pittsburgh	Salamanca, N. Y.
yon, Tracy		A. G. M., Chicago Great Western	St. Paul, Minn.
acBain, D. R		A. S. M. P., Michigan Central	Detroit, Mich.
acbeth, Jas		M. C. B., N. Y. C. & H. R. R. R	East Buffalo, N. Y.
acDonald, T. D		M. M., Des Moines, Iowa Falls & Nor	Iowa Falls, Iowa.
acfarlane, T. W		Mobile, Jackson & Kansas City	Louisville, Miss.
achesney, A. G		Baldwin Locomotive Works	Philadelphia, Pa.
achin, A. M		M. M., St. L., Iron Mntn. & Southern	Baring Cross, Ark.
ackenzie, John			60 Hawthorne ave., Cleveland, Ohio.
agarvey, J. R		American Locomotive Co	Dunkirk, N. Y.
aher, P		S. M. P., Toledo, St. Louis & Western	Frankfort, Ind.
ahl, F. W		M. E., Southern Pacific	San Francisco, Cal.
ailer, John		M. M., Ft. Smith & Western	Ft. Smith, Ark.
alone, I. M			Chihuahua, Mex.
althaner, W		M. M., Delaware & Hudson	Green Island, N. Y.
allinson, E. P			49 Ashford st., Brooklyn, N. Y.
anchester, A. E		S. M. P., C. M. & St. P	West Milwaukee, Wis.
anchester, H. C		A. M. M., Boston & Maine	Mechanicsville, N. Y.
'anning, J. H	336	*S. M., Delaware & Hudson*	*Albany, N. Y.*
annion, T. D		M. M., Philadelphia & Reading	Camden, N. J.
archbanks, James		Wellington & Manawatu	Wellington, N. Z.
arden, J. W		A. M. C. B., Boston & Maine	Boston, Mass.
arkle, T. M			Seattle, Wash.
arshall, E. S			St. Louis, Mo.
arshall, Thos		M. M., C. St. P. M. & O. Ry	St. Paul, Minn.
arshall, W. H		Prest., American Locomotive Co	New York City.
ay, H. C		M. M., C. C. C. & St. L	Louisville, Ky.
aysilles, J. H			1110 Union st., Schenectady, N. Y.
cArthur, F. A		M. M., St. Louis & San Francisco	Springfield, Mo.
cCarthy, M. J		M. M., Lake Shore & Mich. Southern	Elkhart, Ind.
cConnell, J. H			1503 Arrott Bldg., Pittsburg, Pa.
cCormick, A		F. M. Hicks & Co	Chicago Heights, Ill.
'cCuen, J. P	230	*S. M. P., C. N. O. & T. P. and A. G. S. Rys*	*Ludlow, Ky.*
cCuen, R. E		M. M., Lexington & Eastern	Lexington, Ky.
cDonough, James		M. M., Chicago, Rock Island & Pacific	Chickasha, I. T.
cDougall, R. M		M. M., Morenci Southern	Morenci, Ariz.
cEldowney, W. E		M. M., Denver, Enid & Gulf	Enid, O. T.
cElvaney, C. T		M. M., Mo., Kansas & Texas	Denison, Tex.
cGie, John		Chicago, Rock Island & Pacific	Shawnee, O. T.
cGoff, J. H		M. M., Atchison, Topeka & Santa Fe	Ft. Madison, Iowa.
cGrath, J. T		M. M., Grand Trunk	Ft. Gratiot, Mich.
cHaffie, A. B		M. M., Intercolonial	Moncton, N. B., Can.
cHattie, T		M. M., Grand Trunk	Montreal, Can.
cIntosh, Wm		S. M. P., Central R. R. of N. J	Jersey City, N. J.
'cGee, G. S	219	*S. M. P., Mobile, Ohio*	*Mobile, Ala.*
cKeen, W. R., Jr		S. M. P., Union Pacific	Omaha, Neb.
cLean, W. J		M. M., Bell., Bay & Brit. Col	Bellingham, Wash.
cLeish, W. J			Evansville, Ind.
cManamy, J		A. M. M., Pere Marquette	St. Thomas, Ont., Can.
cMasters, Chas. J		M. M., Rutland	Malone, N. Y.
cNabb, T		M. M., A. R. & C. Co	Lethbridge, Alb., Can.
cNaughton, Jas		American Locomotive Co	Schenectady, N. Y.
cNulty, F. M		M. M., Monongahela Connecting	Pittsburgh, Pa.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1905	McRae, J. A		M. E., Michigan Central	Detroit, Mich.
1888	Medway, John			169 8th st., Troy, N. Y.
1905	Meister, C. L		M. E., Atlantic Coast Line	Wilmington, N. C.
1895	Mellin, C. J		American Locomotive Co	Schenectady, N. Y.
1900	Mendenhall, C. M		American Steel Foundries	New York City.
1903	*Menzel, W. G*	190	*S. M. P., Wisconsin Central*	*Fond du Lac, Wis.*
1892	Mertsheimer, F		S. M., K. C. Southern	Pittsburg, Kan.
1887	Michael, J. B		M. M., Southern	Knoxville, Tenn.
1885	Millen, Thos		M. M., Metropolitan Street Ry	106 W. 51st st., N. Y.
1889	*Miller, E. A*	180	*S. M. P., N. Y. C. & St. L*	*Cleveland, Ohio.*
1890	Miller, Geo. A		M. M., Florida East Coast	St. Augustine, Fla.
1903	Miller, J. B		G. F., St. L. Southwestern of Texas	Waco, Tex.
1901	Miller, S. W			
1906	Miller, Wm		A. S. M. P., Denver & Rio Grande	Denver, Colo.
1903	Miller, W. J		M. M., St. L. Southwestern of Texas	Tyler, Tex.
1903	Milliken, James		S. M. P., Phila., Balt. & Washington	Wilmington, Del.
1893	Minshull, P. H		M. M., N. Y. O. & W	Middletown, N. Y.
1892	Minto, H. M		M. M., Louisville & Nashville	Mobile, Ala.
1888	Minton, A. B		M. M., Mobile & Ohio	Jackson, Tenn.
1892	Mitchell, A. E			So. Bethlehem, Pa.
1903	Moir, William		G. M. M., Northern Pacific	So. Tacoma, Wash.
1898	Moler, A. L			Peru, Ind.
1901	Monahan, J. J		M. M., Louisville & Nashville	Paris, Tenn.
1890	Monkhouse, H		Rome Loco. & Mach. Works	Rome, N. Y.
1903	Monlaverde, F		Paulista	Santos, Brazil.
1903	Monroe, M. S		M. M., Chicago, Lake Shore & Eastern	Chicago, Ill.
1884	Montgomery, Wm		M. M., Central of N. J	Lakehurst, N. J.
1901	Morgan, J. B		G. M. M., Toledo & Ohio Central	Bucyrus, Ohio.
1890	Moore, J. H		M. M., Erie	Rochester, N. Y.
1896	Moran, Robert		M. M., Louisville & Nashville	Nashville, Tenn.
1887	Morris, W. S			813 W. Berry st., Ft. Wayne, Ind.
1905	Morrison, J. R		M. M., Inverness Ry. & Coal Co	Inverness, C. B., Can.
1906	Mowery, J. N		M. E., Lehigh Valley	So. Bethlehem, Pa.
1901	Muchnic, C. M		American Locomotive Co	New York, N. Y.
1904	Mudd, G. W		M. M., Wabash	Moberly, Mo.
1903	Mudd, H. K			Richmond, Ind.
1899	*Muhlfeld, J. E*	1843	*G. S. M. P., Balto. & Ohio*	*Baltimore, Md.*
1905	Mullen, D. J		M. M., C. C. C. & St. L	Mt. Carmel, Ill.
1904	Murphy, J. H		M. M., Cin., New Orleans & Tex. Pac	Ludlow, Ky.
1890	Murphy, P. H		Murphy Car Roof Co	East St. Louis, Ill.
1905	Murray, W. H			Chicago, Ill.
1903	Murrian, W. S		M. M., Southern	Alexandria, Va.
1904	Needham, E. F		M. M., Wabash	Ft. Wayne, Ind.
1905	Nelson, E. D		E. of T., Pennsylvania	Altoona, Pa.
1894	Nettleton, W. A		G. S. M. P., St. L. & San Francisco	St. Louis, Mo.
1898	Neubert, G. T		M. M., Kansas City Belt	Kansas City, Mo.
1892	Neuffer, John G		A. S. M., Illinois Central	Chicago, Ill.
1901	Neville, John			Acambaro, Mex.
1896	Neward, F. H		M. M., Pontiac, Ox. & Northern	Pontiac, Mich.
1906	Newhouse, J. F		M. M., Ken. & Ind. Bridge & R. R	Louisville, Ky.
1904	Nicholls, J. Mayne			Iquique, Chili, S. A.
1875	Noble, L. C			Fisher Bldg., Chicago, Ill.
1902	Nolan, J. C		M. M., Arkansas Southern	Ruston, La.
1899	Nolan, J. P		M. M., Morgan's L. & T. R. R. & S. S. Co	Algiers, La.
1906	Noyes, C. T		S. S., Southern Pacific	Sacramento, Cal.

NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
Nutt, Geo. B		L. S., Egyptian State Ry	Cairo, Egypt.
Nuttall, W. H		M. M., Manistee & Northeastern	Manistee, Mich.
O'Beirne, P.		S. M., Toluca, Marquette & Northern	Toluca, Ill.
O'Brien, John		M. M., Southern	Manchester, Va.
O'Hearne, J. E		M. M., Wheeling & Lake Erie	Norwalk, Ohio.
O'Herin, Wm		S. M., Mo., Kan. & Tex	Parsons, Kan.
O'Leary, D		M. M., Pacific Coast	Seattle, Wash.
Oplinger, J. W		S. M. P., Atlantic Coast Line	Savannah, Ga.
Ord, C. R		M. M., Canadian Pacific	McAdam Jct., N. B., Can.
Owens, W. H		M. M., Southern	Manchester, Va.
Parish, LeGrand		S. M. P., L. S. & M. S	Cleveland, Ohio.
Parker, M. B		M. M., Rockwood & Tenn. River	Rockwood, Tenn.
Parks, Geo. E		M. M., Michigan Central	Jackson, Mich.
Park, S. T		S. M. P., Chicago & Eastern Illinois	Danville, Ill.
Park, P. D		M. M., Reid Newfoundland Co.'s	Whitbourne, N. F.
Passmore, H. E		M. M., Toledo & Ohio Central	Kenton, Ohio.
Patterson, J. S			Galena Signal Oil Co., Cincinnati, Ohio.
Patterson, Robt		M. M., Rio Grande Southern	Ridgway, Colo.
Paul, W. M		M. M., Gal., Houston & Henderson	Galveston, Tex.
Paxton, Thos		S. M. P., El Paso & South Western	Douglas, Ariz.
Pearce, J. S		M. M., Norfolk & Western	Portsmouth, Ohio.
Pearsall, D. M		M. M., Atlantic Coast Line	Florence, S. C.
Pearse, H		Buenos Ayres & Rosario, La Quinta,	Rosario de Santa Fe, Arg. Rep., S. A.
Peck, Peter H	75	*M. M., C. & W. I. and Belt*	*Chicago, Ill.*
Pengelly, J. H			City of Mexico, Mex.
Pennington, J. H			Drifton, Pa.
Peyton, H. T		M. M., Atchison, Topeka & Santa Fe	Wellington, Kan.
Pflager, H. M		Commonwealth Steel Co	St. Louis, Mo.
Phillips, C		M. M., New Orleans & Northeastern	Meridian, Miss.
Phipps, S		M. M., Can. Pacific	Revelstroke, B. C.
Piccioli, J		M. M., Colorado & Wyoming	Pueblo, Colo.
Pierce, F. M		M. M., Hawkinsville & Florida Sou	Pitts, Ga.
Pilcher, J. A		M. E., Norfolk & Western	Roanoke, Va.
Pinheiro, Antonio		Mogyana R. R	Campinos, Brazil, S. A.
Place, F. E		Buda Foundry & Machine Co	Harvey, Ill.
Plank, P. D		M. M., Louis., Hend. & St. L	Cloverport, Ky.
Platt, J. G		E. of T., Erie	Meadville, Pa.
Player, John			319 Franklin ave., River Forest, Ill.
Pollitt, Harry		Great Central	Fernlea, Altricham, Cheshire, Eng.
Poole, A. J.		M. M., Seaboard Air Line	Atlanta, Ga.
Post, W. F		Watkins Fdy. & Mach. Co	Hattiesburg, Miss.
Potton, J		M. M., Texas & Pacific	Big Springs, Tex.
Powell, V. U		M. M., Illinois Central	Mattoon, Ill.
Powers, M. J		M. M., Delaware & Hudson	Carbondale, Pa.
Pratt, E. W		M. M., Chicago & North-Western	Missouri Valley, Iowa.
Prendergast, W. H		M. M., Central of Georgia	Columbus, Ga.
Prescott, C. H		M. M., Great Northern	Great Falls, Mont.
Preston, Robert		M. M., Canadian Pacific	Toronto Jct., Toronto, Can.
Prince, S. F., Jr			122 W. 49th st., New York, N. Y.
Purdy, Jos. B		M. M., Hilo	Hilo, Hawaii.
Purves, T. B., Jr.			185 Summer st., Boston, Mass
Quayle, Robert	1307	*S. M. P. & M., Chicago & N.-W*	*Chicago, Ill.*
Quereau, C. H		S. E. E., N. Y. C. & H. R	New York, N. Y.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1890	Randolph, L. S		Virginia Polytechnic Institute	Blacksburg, Va.
1903	Records, J. W		M. M., St. L., Rocky Mtn. & Pacific	Raton, N. M.
1901	Redding, D. J		M. M., Pitts. & Lake Erie	McKee's Rocks, Pa.
1904	Reeves, P. H		M. M., Baltimore & Ohio	Chillicothe, Ohio.
1902	Reid, W. L		American Locomotive Co	Schenectady, N. Y.
1883	Renshaw, W		S. M., Illinois Central	Chicago, Ill.
1892	Rettew, C. E		D. & H. Co	Carbondale, Pa.
1896	Reynolds, O. H			132 Nassau st., New York City.
1899	Rhodes, L. B		M. M., Georgia Southern & Florida	Macon, Ga.
1905	Rice, J. H		M. M., De Queen & Eastern	De Queen, Ark.
1901	Richmond, W. H		M. M., Lake Superior & Ishpeming	Marquette, Mich.
1903	Rickard, W. W			Tucson, Ariz.
1894	Riley, George N		M. M., McKeesport Connecting	Pittsburg, Pa.
1902	Robb, J. M		M. M., Chicago Great Western	Chicago, Ill.
1901	Robb, W. D		S. M. P., Grand Trunk	Montreal, P. Q.
1901	Roberts, Jos		M. M., Union Pacific	Armstrong, Kan.
1896	Roberts, J. W			1237 Bellefontaine st., Indianapolis, Ind.
1891	Roberts, Mord			St. Louis, Mo.
1895	Robinson, Frank		Robinson Co	Boston, Mass.
1903	Robinson, Maynard		M. M., Gulf, Colo. & Santa Fe	Silsbee, Tex.
1906	Roesch, F. P		M. M., Southern	Birmingham, Ala.
1896	Rogers, M. J			1008 West 24th st., Kansas City, Mo.
1903	Rogers, R. H		M. M., N. Y. N. H. & Hartford	Boston, Mass.
1900	Roope, Thos		S. M. P., Chicago, Burl. & Quincy	Lincoln, Neb.
1896	Rosing, W. H. V		M. E., Missouri Pacific	St. Louis, Mo.
1904	Rova, Isaac		Illinois Central	East St. Louis, Ill.
1895	Royal, C. B			151 Franklin ave., Oak Park, Ill.
1898	Rumney, T		A. M. S., Erie	Meadville, Pa.
1896	Rusch, Peter C		M. M., Buffalo, Roch. & Pittsburg	Bradford, Pa.
1903	Russell, W. H		M. M., Southern Pacific	Oakland, Cal.
1893	Ryan, E		M. M., Gal., Houston & San Antonio	San Antoinio, Tex.
1891	Ryan, J. J		S. M. P., Southern Pacific	Houston, Tex.
1892	Ryan, Patrick		M. M., Louisville & Nashville	Russellville, Ky.
1906	Sakuma, T		S. M. P., Kinshui	Moji, Japan.
1892	Sague, J. E		American Locomotive Co	111 Broadway, N. Y.
1887	Sample, N. W		Baldwin Locomotive Works	Philadelphia, Pa.
1896	*Sanderson, R. P. C.*	342	*S. M. P., Seaboard Air Line*	*Portsmouth, Va.*
1903	*Scheffer, F. H*	234	*S. M. P., Nashville, Chatt. & St. Louis*	*Nashville, Tenn.*
1903	Schilling, R. P		M. M., Dela., Lack. & Western	Utica, N. Y.
1905	Schlacks, W. J		S. M., Colorado Midland	Colorado City, Colo.
1904	Schlafge, Wm		M. M., Erie	Jersey City, N. J.
1901	Seabrook, C. H		M. M., St. Louis Southwestern	Pine Bluff, Ark.
1875	Sedgwick, E. V			Galena Signal-Oil Co., Franklin, Pa.
1900	Seidell, G. W		M. M., Southern	Birmingham, Ala.
1900	Seley, C. A		M. E., Chicago, Rock Island & Pacific	Chicago, Ill.
1903	Sheahan, J. F		M. M., Southern	Columbia, S. C.
1899	Shepard, L. A			32 Broadway, New York City.
1903	Shepard, Samuel,		M. M., Minn., St. P. & S. Ste. Marie	Enderlin, N. D.
1905	Shields, A		M. M., Canadian Northern	Winnipeg, Man., Can.
1906	Shields, H. C		Supt., Lehigh & New England	Pen Argyl, Pa.
1904	Shoemaker, H		M. M., Del., Lack. & Western	Scranton, Pa.
1906	Shreve, W. J		M. M., Minn. & Rainy River	Deer River, Minn.
1883	Sinclair, Angus			136 Broadway, New York City.
1900	Singer, Frank		M. M., Midland Terminal	Canon City, Colo.
1892	Sinnott, W		M. M., Baltimore & Ohio	58th st., Phila., Pa.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1889	Skinner, H. M. C			579 Durfee st., Fall River, Mass.
1893	Slater, Frank		M. M., Chicago & North-Western	Escanaba, Mich.
1894	Slayton, C. E		M. M., Deepwater	Page, W. Va.
1900	Slayton, F. T		M. M., St. Joseph & Grand Island	St. Joseph, Mo.
1889	*Small, H. J*	1170	*G. S. M. P., Southern Pacific*	*Oakland, Cal.*
1903	Smith, C. B		M. M., Boston & Maine	Boston, Mass.
1900	Smith, D. A		M. M., Boston & Maine	E. Somerville, Mass.
1904	Smith, E. J		M. M., Atlantic Coast Line	Jacksonville, Fla.
1893	Smith, F. B			35 Hazzard st., Jamestown, N. Y.
1896	Smith, F. C		American Locomotive Co	Manchester, N. H.
1900	Smith, F. J		M. M., B. & O. S.-W	Washington, Ind.
1892	Smith, John L		G. F., Pitts., Shawmut & Northern	St. Marys, Pa.
1900	Smith, L. L		M. M., Scheneetady Street Ry	Schenectady, N. Y.
1899	Smith, R. D			Lincoln, Neb.
1905	*Smith, R. E*	538	*A. G. M., Atlantic Coast Line*	*Wilmington, N. C.*
1902	Smith, Wm		Lyman Mfg. Co	East Buffalo, N. Y.
1869	Smith, W. T		M. M., Chesapeake & Ohio	Covington, Ky.
1903	Smitham, N. L		M. M., Texas Central	Walnut Springs, Tex.
1906	Smock, F. A		G. F., Penna. R. R	Meadows, N. J.
1891	Soule, R. H			1571 Beacon st., Brookline, Mass.
1901	Squire, W. C		Loco. Appliance Co	400 Old Colony Bldg., Chicago, Ill.
1898	Stansbury, C. M		G. F., Chicago, Rock Island & Pacific	Peoria, Ill.
1898	Stevenson, C. E		S. M. P., Mogyana	Campinos, San Paulo, Brazil, S. A.
1903	Stewart, A		M. S., Southern	Washington, D. C.
1906	Stewart, A. F		M. M., Chesapeake & Ohio	Clifton Forge, Va.
1906	Stewart, C. J		M. M., Central New England	Hartford, Conn.
1900	Stewart, M. D		Fitz-Hugh Luther Co	Chicago, Ill.
1885	Stewart, O		S. M. P., Bangor & Aroostook	Oldtown, Me.
1905	Stewart, T. R		M. M., Baltimore & Ohio	Cumberland, Md.
1890	Stillman, H		E. of T., Southern Pacific	Oakland, Cal.
1896	Stocks, W. H			5851 Indiana ave., Chicago, Ill.
1905	Struthers, Alex		M. M., Denver, Northwestern & Pac	Denver, Colo.
1890	Studer, A. L			Denver, Colo.
1901	Sullivan, J. J		M. M., Louisville & Nashville	New Decatur, Ala.
1891	Summerskill, T. A			St. Albans, Vt.
1892	Sumner, Eben T		M. M., Boston & Maine	E. Cambridge, Mass.
1899	Suzuki, S		S. M. P., Kinshui	Moji, Japan.
1901	Swoyer, H		Rogers Locomotive Works	Paterson, N. J.
1899	Symington, T. H			St. Paul Bldg., Baltimore, Md.
1892	Symons, W. E		Pioneer Cast Steel Truck Co	Postal Telegraph Bldg.,Chicago, Ill.
1894	Taft, Wm. H		Boston & Albany	Allston, Mass.
1883	Tandy, H		Supt. Canadian Loco. Works	Kingston, Ont., Can.
1896	Tawse, Robert		M. M., Ann Arbor	Owosso, Mich.
1893	Taylor, C. M		M. S., Atchison, Topeka & Santa Fe	La Junta, Colo.
1901	Taylor, H. D		S. M. P. & R. E., Phila. & Reading	Reading, Pa.
1893	Taylor, Wm. H		M. M., N. Y., Susq. & Western	Stroudsburg, Pa.
1905	Taylor, W. M		M. M., Thornton & Alexandria	Thornton, Ark.
1903	Teat, W. F		M. M., Atlanta, Knox. & Northern	Blue Ridge, Ga.
1905	Temple, C. H		M. M., Canadian Pacific	Winnipeg, Man.
1904	Terrill, C. H		M. M., Chesapeake & Ohio	Huntington, W. Va.
1904	Thomas, E		S. M. P., Andino Ry	Rio Cuarto, Arg. Rep., S. A.
1891	Thomas, H. T		M. M., Detroit & Mackinac	East Tawas, Mich.
1903	Thomas, P. G		M. M., Central R. R. of N. J	Ashley, Pa.
1892	Thomas, J. J., Jr		M. M., Atlantic Coast Line	So. Rocky Mtn., N. C.
1883	Thomas, W. H			4230 Spruce st., Philadelphia, Pa.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1901	Thomas, W. J		Christobal Shops	Canal Zone.
1890	Thompson, C. A			Morris Park, Long Island, N. Y.
1903	Thompson, E. B		A. S. M. P., Chicago & North-Western	Chicago, Ill.
1896	Thompson, Geo		M. M., Union Pacific	Omaha, Neb.
1902	Thompson, W. O		S. M. P., N. Y. C. & H. R	Oswego, N. Y.
1895	Thompson, W. T			38 Anderson place, Buffalo, N. Y.
1902	Thornton, Chas. J		L. S., United Rys. of Havana	Havana, Cuba.
1883	Thow, Wm		Government	Eveleigh, N. S. W.
1903	Tinker, J. H		M. M., Illinois Central	Mounds, Ill.
1903	Todd, A. B		M. M., Southern California	San Bernardino, Cal.
1892	Todd, Louis C		M. M., Boston & Maine	Charlestown, Mass.
1898	Tollerton, W. J		S. M. P., Chicago, Rock Island & Pacific	Topeka, Kan.
1901	Toltz, Max		Manistee & Grand Rapids	Manistee, Mich.
1893	Tonge, John		M. M., Minneapolis & St. Louis	Minneapolis, Minn.
1903	Torrey, F. A		S. M. P., Chicago, Bur. & Quincy	Chicago, Ill.
1896	Tracy, W. L		M. M., Louisville & Nashville	Louisville, Ky.
1892	Traver, W. H		Chicago Pneumatic Tool Co	Chicago, Ill.
1883	Tregelles, Henry		Care Norton, Megaw & Co.,	Rio de Janeiro, Brazil.
1890	Tuggle, S. R		S. M. P., Houston & Texas Central	Houston, Tex.
1903	Tuma, Frank		M. M., Erie	Buffalo, N. Y.
1903	Turnbull, A. G		A. M. S., Erie	Meadville, Pa.
1899	Turner, A		M. M., Lehigh Valley	South Easton, Pa.
1890	Turner, Calvin G		M. M., Phila., Balt. & Washington	Wilmington, Del.
1889	Turner, Chas. E			Rochester, N. Y.
1906	Turner, J. A.		M. M., C. St. P. M & O. Ry	Itasca, Minn.
1886	Turner, J. S			24 Broad st., N. Y. City.
1890	*Turner, L. H*	189	*S. M. P., Pittsburg & Lake Erie*	*Pittsburg, Pa.*
1906	Turtle, J. A		M. M., Union Pacific	Denver, Colo.
1904	Uddenberg, C. E		A. S. M. P., Swedish Government	Boden, Sweden.
1898	Van Alstyne, D		M. S., Northern Pacific	St. Paul, Minn.
1905	Vanaman, C. D		M. M., Florida East Coast	St. Augustine, Fla.
1904	*Van Buskirk, H. C.*	172	*S. M. P., Colorado & Southern*	*Denver, Colo.*
1896	Van Cleve, J. R		M. M., Alaska Central	Seward, Alaska.
1904	Van Doren, G. L		S. S., Central R. R. of New Jersey	Elizabethport, N. J.
1905	Van Ripper, D. F		G. F., Erie	Meadville, Pa.
1891	Vauclain, Samuel M		Baldwin Locomotive Works	Philadelphia, Pa.
1898	*Vaughan, H. H*	550	*Asst. to V. P., Canadian Pacific*	*Montreal, Can.*
1903	Vernet, C. C		S. M. P., Western Ry. of Havana	Havana, Cuba.
1896	Villasenor, Alberto			San Jose de Costa Rica, C. A.
1892	Vogt, A. S		M. E., Pennsylvania	Altoona, Pa.
1899	Vought, J. H			346 Linwood ave., Buffalo, N. Y.
1904	Waddington, John		Central Northern R. R	S. Cristobal, Arg. Rep., S. A.
1904	Wagstaff, George		S. B., New York Central Lines	Buffalo, N. Y.
1905	Wahlen, John		M. M., Montpelier & Wells River	Montpelier, Vt.
1892	Waitt, A. M			17 Battery place, New York City, N. Y.
1893	Walker, Henry E		Buenos Aires Western	Buenos Ayres, Arg. Rep., S. A.
1904	*Wallace, W. G.*	58	*S. M. P., Duluth, Missabe & Northern*	*Duluth, Minn.*
1888	Wallis, Phillip			Richmond Hill, L. I., N. Y.
1900	*Walsh, F. O*	32	*M. M., A. & W. P. & W. Ry. of Ala*	*Montgomery, Ala.*
1903	Walsh, J. F		S. M. P., Chesapeake & Ohio	Richmond, Va.
1874	Walsh, Thos		M. M., Louisville & Nashville	Howell, Ind.
1902	Walsh, W. C		M. M., Missouri Pacific	Ft. Scott, Kan.
1896	Walton, E. A		S. M. P., N. Y. C. & H. R	Avis, Pa.

JOINED.	NAME.	NO. OF LOCOS.	ROAD.	ADDRESS.
1883	Warren, Beriah			1619 Pennsylvania ave., St. Louis, Mo.
1882	Warren, W. B			1619 Pennsylvania ave., St. Louis, Mo.
1903	Waters, J. J		S. M. D., Mex. International	Ciudad Porfirio Diaz, Mex.
1902	Watson, Samuel		M. M., N. Y. C. & H. R	W. Albany, N. Y.
1904	Watters, J. H		A. M. M., Georgia	Augusta, Ga.
1883	Watts, Amos H		M. M., Cincinnati Northern	Van Wert, Ohio.
1900	Welch, C. H		M. M., Midland Valley	Excelsior, Ark.
1903	Wellisch, Louis			693 Hague ave., St. Paul, Minn.
1906	Wells, M. E		A. M. M., Wheeling & Lake Erie	Mass'llon, Ohio.
1880	*West, G. W*	167	*S. M. P., N. Y. O. & W*	*Middletown, N. Y.*
1899	Westmark, H. O			164 So. River st., Aurora, Ill.
1903	Whale, George		London & Northwestern	Crewe, England.
1903	Whetstone, John		A. S. M. P., Norfolk & Southern	Berkley, Va.
1885	White, A. M		American Locomotive Co	Manchester, N. H.
1894	White, E. T		S. M. P., Baltimore & Ohio	Mt. Clare, Baltimore, Md.
1901	White, W			225 Ry. Exchange Bldg., Chicago, Ill.
1898	Whyte, F. M		C. M. E., N. Y. Cent. Lines	New York City.
1905	Wickhorst, M. H		E. of T., Chicago, Burl. & Quincy	Aurora, Ill.
1899	Wiest, E. N		M. M., Man. & North-Eastern	Manistee, Mich.
1894	Wiggin, Chas. H		M. M., Boston & Maine	Malden, Mass.
1878	Wightman, D. A			Warren, R. I.
1900	Wilbur, I. N		M. M., Chicago, Burl. & Quincy	Hannibal, Mo.
1891	Wilcox, W. J		M. M., Mexican Central	Chihuahua, Mex.
1901	Wildin, G. W		M. S., Erie	Meadville, Pa.
1896	Williams, Alfred		Paulista	Paulista, Brazil, S. A.
1905	Williams, C. R		G. M. M., Buffalo & Susquehanna	Galeton, Pa.
1891	Williams, E. A		G. M. S., Erie	New York, N. Y.
1903	Williams, F. W			Lyndhurst, N. J.
1905	Willius, Gustav, Jr		M. E., Great Northern	St. Paul, Minn.
1905	Wilson, Charles		M. M., Lehigh Valley	Wilkesbarre, Pa.
1906	Wilson, D. H., Jr		Elec. Engr., Erie	Meadville, Pa.
1887	Wilson, G. F		P. A., Del., Lack. & Western	New York City.
1901	Wilson, W. H		S. M. P., Buffalo, Roch. & Pittsburg	Du Bois, Pa.
1900	Wirt, G		M. M., C. C. C. & St. L	Delaware, Ohio.
1906	Woodbridge, H. C		M. M., Buffalo, Rochester & Pittsburgh	E. Salamanca, N. Y.
1903	Woodruff, S. N		M. M., Minn., St. P. & S. Ste. Marie	Gladstone, Mich.
1903	Worsdell, Wilson		C. M. E., North-Eastern	Gateshead-on-Tyne, Eng.
1901	Wright, R. V		American Engineer	285 N. 20th st., E. Orange, N. J.
1903	Yergens, W. F		M. M., Erie	Huntington, Ind.
1896	Yohn, C. R		M. M., H. & B. T. Mtn	Saxton, Pa.
1899	York, C. C		B. A. & Pac. Estacion Junin, Buenos Ayres, Arg. Rep., S. A.	
1902	Young, C. B		M. E., Chicago, Burlington & Quincy	Chicago, Ill.
1905	Young, R. R		M. M., Atlantic Coast Line	Waycross, Ga.
1895	Young, W. H		M. M., Atlantic Coast Line	Savannah, Ga.
1898	Zerbee, F. J		M. M., C. C. C. & St. L	Bellefontaine, Ohio.

ASSOCIATE MEMBERS.

JOINED.	NAME.	ADDRESS.
1893	Baker, Geo. H	227 Monroe st., Brooklyn, N. Y.
1898	Basford, G. M	Amer. Loco. Co., 111 Broadway, New York City.
1898	Bates, E. C	Lock Box 1544, Boston, Mass.
1903	Casey, F. A	271 Franklin st., Boston, Mass.
1896	Fowler, Geo. L	53 Broadway, New York City.
1895	Goss, W. F. M	Purdue University, Lafayette, Ind.
1889	Hill, John A	80 Munn ave., E. Orange, N. J.
1904	Hodgins, George	136 Liberty st., New York City.
1899	Kneass, Strickland L	Wm. Sellers Co., Ltd., Philada., Pa.
1901	Lane, F. W	*Railway Age*, Monadnock Bldg., Chicago, Ill.
1904	Lanza, Gaetano	Mass. Inst. of Technology, Boston, Mass.
1901	Player, John	American Loco. Co., Brooks Works, Dunkirk, N. Y.
1889	Pomeroy, L. R	General Electric Co., 44 Broad st., New York City.
1899	Smart, R. A	Westinghouse E. & M. Co., Pittsburgh, Pa.
1882	Smith, W. A	Manhattan Bldg., Chicago, Ill.
1899	Street, Clement F	Westinghouse E. & M. Co., Pittsburgh, Pa.
1903	Taylor, Jos. W	390 Old Colony Bldg., Chicago, Ill.

HONORARY MEMBERS.

JOINED.	NAME.	ROAD.	ADDRESS.
1885	Becker, Andrew		New Decatur, Ala.
1883	Blackwell, Chas		Mt. Lookout, Cincinnati, Ohio.
1879	Cooke, Allen		Danville, Ill.
1869	Coolidge, G. A		Barnard ave., Watertown, Mass.
1870	Cooper, H. L		Chesterton, Ind.
1876	Cory, Chas. H		Lima, Ohio.
1895	Coster, E. L.	Residence, Irvington-on-Hudson	Broad Exchange Bldg., 25 Broad st., N. Y. City.
1885	Cromwell, A. J.		1411 Hollins st., Baltimore, Md.
1870	Divine, J. F	Atlantic Coast Line	Wilmington, N. C.
1881	Eastman, A. G		Sutton, Que.
1871	Forney, M. N		501 Fifth ave., New York City.
1872	Foss, J. M	Cent. Vermont	St. Albans, Vt.
1885	Galloway, A	C. H. & D	Cincinnati, Ohio.
1871	Hewitt, John		1323 So. Jefferson st., St. Louis, Mo.
1874	Jeffery, E. T	Denver & Rio Grande	Denver, Colo.
1868	Johan, Jacob		Springfield, Ill.
1868	Kinsey, J. I	Lehigh Valley	Easton, Pa.
1873	Lewis, W. H		Hoboken, N. J.
1878	Maglenn, Jas	Seaboard Air Line	Raleigh, N. C.
1869	McKenna, John		2005 N. Alabama ave., Indianapolis, Ind.
1871	Miles, F. B		Bement & Miles, Philadelphia, Pa.
1885	Paxson, L. B	Philadelphia & Reading	Reading, Pa.
1872	Philbric, J. W		Waterville, Me.

JOINED.	NAME.	ROAD.	ADDRESS.
1878	Pilsbury, Amos		Portland, Me.
1874	Place, T. W		Waterloo, Iowa.
1887	Rhodes, Godfrey W		Quebec, P. Q., Can.
1869	Richards, George		14 Auburn st., Roxbury, Mass.
1870	Robinson, W. A		Hamilton, Ont.
1869	Sellers, Morris		Western Union Bldg., Chicago, Ill.
1874	Schlacks, Henry		Denver, Colo.
1868	Shaver, D. O		Pittsburg, Pa.
1888	Sheppard, F. L	Pennsylvania	Altoona, Pa.
1891	Sheer, J. M		514 Seventh st., East St Louis, Ill.
1868	Sprague, H. N		Jamestown, N. Y.
1869	Setchel, J. H		Cuba, N. Y.
1875	Strode, Jas		Elmira, N. Y.
1883	Sullivan, A. W	Illinois Central	Chicago, Ill.
1869	Thompson, John		51 Lakewood Road, Newton Highlands, Mass.
1870	Towne, H. A		54 S. Third st., Minneapolis, Minn.
1883	Twombly, F. M		18 Farquhar st., Rosindale, Mass.
1868	Wells, Reuben		Paterson, N. J.

PROCEEDINGS.

MONDAY'S SESSION.

President H. F. Ball called the meeting to order at 9:30 o'clock.

PRESIDENT BALL: Following our usual custom of opening our meeting with prayer, I take pleasure in calling upon the Rev. Newton W. Cadwell, of the Olivet Presbyterian Church, to invoke the Divine blessing.

Doctor Cadwell offered prayer.

THE PRESIDENT: Seats have been reserved on the platform for the past presidents of the Master Car Builders' Association and the Master Mechanics' Association, and if any of these gentlemen are in the audience, we shall be pleased to have them step forward and take seats on the platform.

We are honored this morning in having with us the Mayor of Atlantic City. He has kindly consented to make a few remarks at this the opening of our thirty-ninth annual convention. I take great pleasure in introducing His Honor, Mayor F. P. Stoy, of Atlantic City.

MAYOR F. P. STOY: Mr. President, Ladies and Gentlemen, the selection played by the band this morning means, as I understand, "Move Quickly," and from what I can judge we are on time. Upon the last occasion when I spoke in this hall I ran up against the Post and I want to say to you I was jarred just a little, but I have recovered from that sensation by this time. He told you that the little speech of welcome which I delivered last week had

been made so many times by me during the last ten years that I had it memorized word for word, because he had heard it so many times before.

I am glad to be present this morning, gentlemen, to welcome you to our city. While you are, perhaps, a separate organization, we have considered you all one family, and when I bade you welcome a few days ago I supposed I was bidding welcome to you all. Nevertheless, we are glad again this morning to perform our part of the work in making you happy here with us, and we hope that this coming together, as I said, will be one of pleasure and benefit to you all.

I am not going to take up your time, Mr. President and gentlemen, with any lengthy remarks. When I say that you are welcome, I want it understood that the city extends to you the freedom of the city, and we expect you to enjoy everything that is to be seen and heard and all the sights in Atlantic City. We know that we are entertaining in Atlantic City to-day one of the greatest institutions that has ever been here. You are giving us, as well as yourselves, the greatest exhibit that has ever been made either on the Steel Pier or any other part of the island, and we congratulate you on the success you have had and the harmony which prevails between the members. When I look around among the heavyweights in this Association and the Master Car Builders' Association, it strikes me as a very intelligent audience and there is no reason why there should not be at some of these meetings "National Possibilities," men able to do, not only the work of these institutions, but well equipped for almost everything that should come up.

We congratulate ourselves this morning in having this class of people with us, and we hope that when you consider the matter of selecting a place for the next meeting you will give thoughtful consideration to Atlantic City, and if you should select our city I assure you that your second coming together here will be even more advantageous to you and your two associations than the present meeting. As a final word, let me express the hope, as representing the people of this city, that your deliberations will be productive of much good to the very important organization which you represent. I thank you, Mr. President and gentlemen.

THE PRESIDENT: I am going to ask one of our worthy ex-presidents to respond to the kindly remarks made by Mayor Stoy. It is not necessary to introduce this gentleman; he is well known to you all — Mr. Arthur M. Waitt. [Applause.]

MR. A. M. WAITT: Your Honor, Mr. President, Ladies and Gentlemen of the convention: I do not know if Mayor Stoy was intentionally making puns on heavy "Waitts" or not [laughter], but it hit me a little hard, starting the perspiration. I want, however, on behalf on the convention, your Honor, to thank you very kindly for your words of welcome. We appreciate them. We have come here knowing that we would have your open-armed, open-handed welcome, and we are enjoying the pleasures here of Atlantic City. We thank you for them. We hope that our stay will continue during the coming week to be as pleasant as it has been to many during the past week.

I do not know very much about the incumbency of political office. I never had the pleasure or the honor to hold one myself, but I happened to hear of a speech the other day that might be a new one to his Honor, and I am going, if I can, just to recite the circumstances. It happened in Detroit — some of the people here are from Detroit, I believe — possibly they know the gentleman; he was an Irishman. He was blessed with wealth; he had not been blessed with very much acquaintance with Roycroft books, mission furniture, and other educational accessories, but he was very popular with the boys, and they thought at a big political convention that they would propose him for chairman, having no idea, of course, that he would accept. But he did, and as he took the chair he spoke something like this:

"Gintlemin of the convention; I want to congratilate yez most heartily upon the choice of your chairman. [Laughter.] You kin rest asshured that so long as the bulluk of the population constitutes the masses of the people there may be no fear from the privilid few. Gintlemin, the convention is now ready for business." [Applause and laughter.]

THE PRESIDENT: Before proceeding with the regular order of business, we have a communication from the Baldwin Locomotive Works, tendering us an invitation to visit their works at Philadelphia at such time as may be deemed most convenient.

The Philadelphia & Reading Railway Company has kindly put at the disposal of such visitors who wish to accept this invitation a special train running from Atlantic City to Camden, and carriages will be at the foot of Walnut street to meet you. At the conclusion of the visit the same means of transportation will convey you back to Atlantic City. It is hoped that all who can will avail themselves of the invitation, and that the secretary will be promptly notified of such acceptance. The Baldwin people desire to have notice as early as possible this morning in order to make the necessary arrangements. It is thought that most of the members who would care to visit the works would wish to go to-morrow afternoon, and if the members decide that they will accept this invitation we will endeavor to have the meeting close as near 12 o'clock as possible and the Baldwin people will provide lunch upon our arrival in Philadelphia. This invitation is before you and we would be glad to have you act upon it immediately. I might add, in addition to what has been said, that the train will return to Atlantic City not later than 6:30, so it will give you ample time to prepare for the ball.

MR. E. A. MILLER (N. Y. C. & St. L. Ry.): I move that we accept the invitation of the Baldwin Locomotive Works to visit their shops to-morrow afternoon, leaving here at the close of our convention session, leaving here at 12:30.

MR. W. H. NUTTALL (Manistee & North Eastern Ry.): I support that motion. (Motion put to a vote and carried.)

THE SECRETARY: Mr. Bright, of the Baldwin Locomotive Works, who has charge of the matter here, says he will furnish the members with badges if they will apply at the enrollment desk at the other end of the pier. I would like to have the members apply just as promptly as they can to-day so that he will have some idea of how many members will go.

MR. NUTTALL: May I inquire whether this will include the ladies?

THE PRESIDENT: That is my understanding.

The next in order is the reading of the address of the President.

Members of the American Railway Master Mechanics' Association, Ladies and Gentlemen:

It is a pleasure and a great privilege to welcome you at the opening of this, the thirty-ninth annual convention of our Association, and I extend to you all a hearty greeting.

From the inception of the Association, thirty-eight years ago, each successive convention has marked a period of advancement in our work. At this meeting we will have presented to us matters of even greater importance than have been considered heretofore, and this convention, above all others, will mean more to us, as representatives of that important factor in railroad transportation — the Motive Power Department — than any of the conventions which have become matters of history.

The past year has been noteworthy as a record-breaker in the continuation of the prosperous conditions which have prevailed during the past decade. Exceptionally favorable weather conditions, combined with large additions to equipment, which our superiors had taken the precaution to provide, enabled the railroads to meet the emergency in a creditable manner. Locomotive and car plants have been taxed to their utmost capacity to meet the requirements of the railroads, whose orders, in many cases, were the largest placed in railroad history.

Statistics compiled for the year 1905 show a large increase in output of new locomotives over the year 1904, as the following data will indicate:

	1905.	1904.	Increase, per cent.
Total number of locomotives built for domestic use and for export by locomotive builders....	5,491	3,441	60
Total number of locomotives built for domestic use by the builders and in railroad shops.....	5,176	3,198	61
Compound locomotives built for domestic use	177	132	34
Balanced compound locomotives built for domestic use.....	76	41	85
Number of electric locomotives built	140	95	47

The tendency in locomotive-building during the year has been along conservative lines, no radical changes in general design being noticeable. The four-cylinder balanced compound has not progressed in general favor as rapidly as was anticipated, its extended use being confined largely to those roads which participated in its early introduction. In view of the economy obtained in tests at the St. Louis testing plant, it is certainly deserving of more attention.

The Mallet type of locomotive, which is specially designed to meet

conditions requiring a very powerful locomotive, is another type which is not being introduced as fast as its merits will warrant.

The most noteworthy change in detail design of the locomotive, one that marks a departure from long-established American practice, is the acceptance of the Walschaert valve gear. This form of valve gear lends itself admirably to the heavy locomotive, having advantages in the way of accessibility for inspection and repairs, lightness and freedom from rapid wear. The rapidity with which this gear has grown in favor with enginemen, as well as those who have to do with the maintenance of the engine, promises well for its future. Up to the 1st of January, 1905, there were 248 locomotives equipped with the Walschaert valve gear in this country; and as an indication of the tendency toward the general adoption of this gear, one road to-day has 225 engines equipped with it.

In boiler design, much has been done incidental to the introduction of the Superheater, and more will undoubtedly follow as designers take up the problem of superheating steam for locomotive engines. Apart from this, the most radical departure in boiler design is found in the use of a combustion chamber, in long boilers using bituminous coal, with attendant remarkable results in overcoming rapid deterioration of flue ends and leaking. It is also worthy of note that the flexible stay bolt is steadily gaining ground.

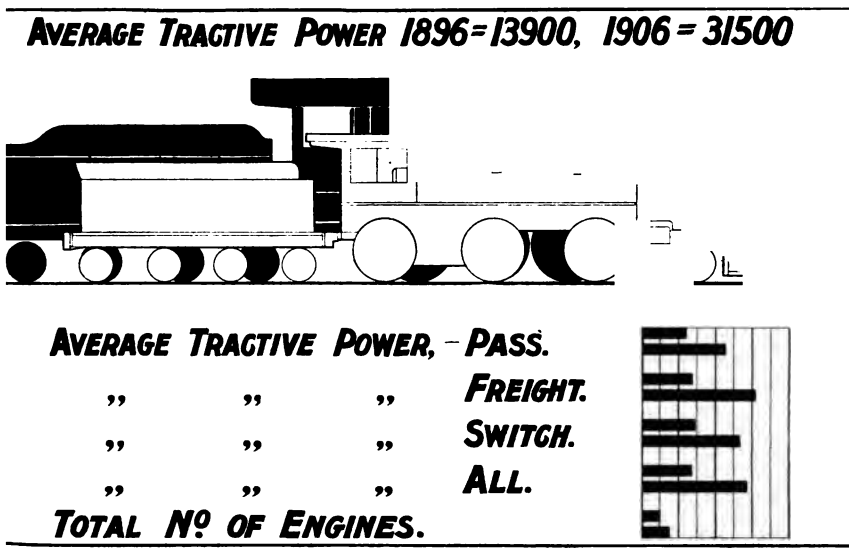
To meet the changed conditions in railway operation, as a result of the growth of the locomotive in recent years, no equipment detail furnishes a better example of progress than the advancement made in railway braking appliances. The problem of braking trains, having from four to five times their former weight, with double the number of cars, has been solved successfully and with apparatus greatly simplified. The new engine and tender equipments represent a consolidation of all previous locomotive equipments, as far as effects are concerned, with a centralization of the functions of the different apparatus into one unit, thereby eliminating a great many parts.

Aside from what has been accomplished in the direction named, changes for economy of operation have also received attention. The introduction of the cross-compound air pump is opportune. The demands for air have increased to such an extent as to represent quite a large percentage of the boiler capacity for its production. It has been found that under normal working of a large freight locomotive, hauling a train of sixty-five cars, fifty of which were air-braked, at twenty miles per hour, the simple air pump requires approximately six per cent of the steam generated. If a portion of this can be saved by compounding, such saving should not be overlooked. Tests which have been made show an economy for the compound pump of sixty per cent over the simple pump.

A list of improvements in details would not be complete without a mention of the advancement made in the art of manufacturing rolled steel wheels. Their increasing use promises well for this type of wheel.

The Motive Power problem — "Reduced cost per ton-mile of transportation" — is presented to us to-day for solution, even more forcibly than it has been presented to those who preceded us, and is deserving of more careful consideration and study than what has been accorded it heretofore. This is not merely a mechanical problem. How has the problem been met from a motive power standpoint? By providing a locomotive, the size of which has only been limited by the governing clearance dimensions. But there is something more that we can do.

It may not be out of place to refer at this time to the advancement that has been made in power capacity during the past ten years, and to reflect with pardonable pride on our having participated in the splendid movement in the upbuilding of the locomotive, which the following figures represent. The data presented were obtained from a road with which you are all familiar and is fairly representative of the progress which has been attained on all roads in the country. To better illustrate the following figures, diagrams have been prepared, which will be shown you.



In the years 1896 and 1906, the average tractive power for each class of engine was as follows:

	1896.	1906.
For freight engines	13,900	31,500
For passenger engines	12,200	22,900
For switching engines	14,700	26,800
For all engines	13,700	28,700
Total number of engines, all classes	551	764

During the period of evolution represented by the foregoing figures, new difficulties arose, new problems required solution. In the desire for adequate boiler capacity within the limits of dimensions and weights imposed, errors were made in boiler design, in restricting the depth of the fire box, in the spacing of the flues and in the use of abnormal grate areas. With the greater use of cast steel, advantage was taken to reduce weights of details, to the extent of contributing the weight thus saved to further increase the boiler dimensions. In some cases, such as wheel centers and frames, the lightness of the parts did not always result in failures, but their weakness contributed to the rapid wear or failure of other dependent parts, and in other cases failure of the parts themselves.

Experience has shown where errors of design have been made and a new basis for future calculations has been evolved, which has placed the present design and construction on even a more satisfactory plane than that obtained with the lighter power. When the large locomotive went into commission, the practices in vogue for the care and maintenance of the locomotive fell short of bringing results; in many cases they brought disaster. Much of this was attributed to poor design, when in reality the trouble lay in other directions. It was found a difficult matter to overcome flue leakage. A study of this subject by very able specialists in the motive power department has resulted in giving us definite rules regarding the care of the boilers, both on the part of the enginemen and roundhousemen, which are being extensively followed, with results as good or better than were formerly obtained. The machinery of the locomotive being heavier, also required special treatment at terminals, involving the adoption of the "stitch-in-time" policy, to keep the engine up to its maximum efficiency and to avoid rapid deterioration, which was found to result from any neglect.

To provide the care necessary for the large locomotive involved the expenditure of large sums for adequate terminals. Facilities for quick and frequent washing of boilers became imperative. Better drop pits and more of them were necessary. Engine houses with heating plants that would heat, and smoke jacks that would ventilate, were required. The lighting of the house at night to provide for a continuous operation of the plant on an efficient basis was a recognized improvement. All this has been accomplished, and to-day we can be congratulated on having reached a plane of excellence, both in the design of the locomotive and in maintenance facilities, whereby the large locomotive is being handled just as expeditiously as the smaller one was a few years ago.

Reports presented to this Association on the subject of Roundhouse Terminals, at two former conventions, have had a marked influence in directing railroads to the appreciation of their shortcomings in the way of adequate terminals and facilities, and have played no small part in bringing about improved conditions.

How shall we meet the motive power problem in the future?

The rapid growth in power which marked the development of the locomotive in the past few years, and by which great economies of operation are being obtained, has apparently been arrested by the limitation of clearances, capacity of the firemen and the reaching of the practicable train length limit. It would therefore appear questionable to look for further economies, as a general proposition, by continuing to enlarge the locomotive, under present conditions. The solution of the problem lies in other directions:

We shall be required to develop the mechanical stoker. Compounding and superheating will be prosecuted with greater vigor than ever. The use of a feed-water heater may be resorted to, and among the smaller items, undoubtedly the compound air pump will be used, and perhaps the variable exhaust nozzle. We now have engines that will run successfully from terminal to terminal, and have reached a plane in the economical maintenance of our locomotives whereby the use of the foregoing fuel-saving devices will make more apparent than heretofore the economies resulting therefrom. While considering the use of fuel-saving devices, we must not lose sight of the economies that may be obtained through individual effort, with the facilities at hand.

This naturally leads to the subject of statistics. In following up fuel consumption on the average railroad, particularly where the pooling system is in vogue, the need for an up-to-date method of determining responsibility for the extravagant use of fuel is very apparent. Given proper weighing facilities, the problem presented is a systematic method for quickly determining at the end of each trip whether or not the coal used was in excess of the work performed, and, if so, the immediate placing of the responsibility either with the crew or engine, as the case may warrant.

Another phase of the motive power problem is the subject of organization. This subject has been referred to by former presidents, and while it is an old theme, it presents increasingly difficult problems, if we would successfully cope with the progress of transportation. To obtain the best results in any organization, no one factor should be overtaxed. The progress of our railroads has been so great and the increase in business, while gradual, has been so persistent, that one is liable to awaken too late to the realization of having an organization inadequate to the demands placed upon it.

Consolidation of properties, and growth, have depreciated positions of the motive power department, compelling men to assume responsibilities beyond their positions. Those who have studied industrial and military organizations find that one officer will supervise not to exceed from twenty-six to thirty men, while in railroad organizations this will extend to 150 men.

In analyzing the results of consolidation, we find a Master Mechanic in charge of two or more divisions, where formerly only one was under

his jurisdiction. After thus greatly increasing his duties, added responsibility was placed upon him by increasing the capacity of the locomotive from fifty to one hundred per cent and rapidly increasing their numbers. The same is true of roads which have not gone through the evolution of consolidation brought about by natural growth.

We find that work is now being performed at important division engine houses of a character that was formerly taken care of at division shops. The work is supervised by the engine house foreman, acting in the capacity of the former Division Master Mechanic, having oftentimes no special advantages at his command in the way of facilities for turning out work, with the disadvantage of an official title, the possession of which gives to the incumbent no consideration for either adequate compensation for services rendered, or proper respect from those under his jurisdiction, or consideration from those in other departments with which he comes in contact. The modern enginehouse requires a bigger general at its head than the former small shop.

What has been said of the enginehouse foreman is also applicable to those subordinate in authority to him, and to those occupying similar positions of equal or greater responsibility in the shops, particularly as to compensation. Increases in wage rates granted to laboring men from time to time very rarely apply to the foremen, with the result, in many cases, of finding the men receiving more per month than those responsible for their direction. It may be stated that overtime rates have much to do with this condition. True, but who puts in more overtime than the average subordinate official, receiving a monthly stipend? An efficient organization, under the conditions mentioned, can not be built up or maintained.

The large railroad to-day should have in its motive power department more Division Master Mechanics, each to have allotted to him for care and maintenance such number of locomotives as can be properly looked after, and to the extent that he may know the shortcomings and weaknesses of each individual engine and be held responsible for their performance and cost of maintenance while out of main shop. This may require his having jurisdiction over two or more engine houses. The main shops on each grand division to be supervised by a shop superintendent, who will be held responsible for cost per unit of shop output; each grand division to be in charge of a division superintendent of motive power, and over the entire department, an official on the staff of the president, having a thorough understanding of the department as to its details and needs, and of sufficient knowledge and experience to present the motive power problem, and to show that it is an element in the operating problem. It is gratifying to note that one such position has recently been created on one of our more important railroads.

Another detail of organization, which is part of the motive power problem, is the establishing of systems of apprenticeship, under proper supervision, whereby the apprentice can and will be assured a thorough,

practical course of training in the shops, and for those who show the aptitude or inclination, a special course, with the end in view of providing sufficient technical training to fit them for positions of responsibility. The apprentice of to-day is rapidly drifting out of sympathy with his employers, by reason of the indifference displayed toward him by those having him in charge. To offset this tendency, he must feel that the employers have his welfare at heart, and this can only be accomplished in these busy times by having an apprentice department with an official at its head, to relieve those in immediate charge. A very thorough and competent organization of this character is now in operation on the New York Central Lines.

Considerable thought and experiment have been devoted during the past year to the development of a motor car, which could be used for branch line service, corresponding to the service furnished by the interurban electric car. The most promising field of effort has been the gasoline motor. Others have followed in the footsteps of our foreign friends and have experimented with steam, using oil for fuel. What the outcome will be can not be conjectured at this time. It is safe to say, however, that with the demand for such a car in sight and American ingenuity at work a satisfactory car will be evolved in due time.

The Association has before it for consideration reports of unusual interest and exceptional value.

The report of Tests of Locomotives at the Louisiana Purchase Exposition terminates the work of the Committee appointed in 1903 to represent this Association on the Pennsylvania R. R. Company's Advisory Committee, and brings to your attention the conclusion of a research of unusual magnitude and value. Beginning in the spring of 1903, the Pennsylvania Railroad System designed and constructed a locomotive testing plant and equipped it with accessory apparatus of every sort. It secured the coöperation of National Engineering Societies in the formation of an Advisory Committee, which committee had an important part in the scientific phases of the work, and it made its plant accessible to other railroad companies which furnished locomotives for test. In this manner it has determined, by methods carefully chosen, with the highest degree of accuracy, the performance of eight typical locomotives and has published in elaborate form a complete description of its methods and a full record of its results. The effect of this whole process and the results developed therefrom, as factors in the upbuilding of the American locomotive of the future, are of unusual significance.

The American Railway Master Mechanics' Association may well congratulate itself that, throughout this process, it has been represented upon the Pennsylvania Company's Advisory Committee by three of its chosen members, who, in coöperation with other eminent engineers, have given their time and attention to the development of the various details concerned in this great work.

The report of the Committee on Locomotive Front Ends represents the work that has been accomplished to date. The investigations thus far conducted have been thorough and complete, and have definitely settled the principles underlying the design of locomotive front ends.

Not only has the law been established connecting the size and proper proportions of the stack with the diameter of the front end, thus completing the previous system of tests initiated by the *American Engineer,* in which the proper proportions of the stack and its relation to the various positions of the nozzle were established for a 54-inch front end, but the various styles of inside stacks, false tops to the smoke box and different arrangements of petticoats have been experimented with, resulting in definitely deciding upon the arrangement which is most satisfactory and economical in service. Sufficient data were also obtained to explain most conclusively the reasons for the large variety of results that have been obtained from time to time in practice with different arrangements of stacks and petticoat pipes. It would appear, from the experiments, that this work has been carried to a completion and that no further work of this nature will be required, unless it be on something totally different to the front end arrangements which have hitherto been employed.

In the successful prosecution of this work we are indebted to the railroads for their generous contributions; to the N. Y. C. & H. R. R. R. for the loan of a large locomotive, and to Doctor W. F. M. Goss for the active part taken in the work, and it is hoped that suitable action will be taken at this convention in testimony of our indebtedness to those just mentioned.

The Association has before it, in the two reports just referred to, examples of research work excellently performed, and it will do well to follow along similar lines in its future investigations. I deem it a great privilege to be your presiding officer on the occasion of the presentation of these important subjects.

The report and discussion on the subject of mechanical stokers should stimulate interest in the development of this exceedingly important detail of locomotive construction. We should know about stokers, and the Association has acted wisely in appointing a standing committee to report progress being made from year to year.

In the discussion of classification of locomotive repairs, an opportunity is presented to get into the commercial questions of the department. This phase of the subject has not received the attention it deserves and herein lies a great opportunity for motive power men.

In discussing the details of enginehouse running repair work it is absolutely necessary to treat the proposition as a whole, with the view of facilitating operations at terminals to meet the needs of the operating department.

The report to be presented on the subject of "Electricity on Steam Railroads" is worthy of the most careful consideration and discussion. In view of the economy obtained in tests of the locomotive on the Pennsyl-

vania testing plant, where it was shown that a locomotive was capable of delivering a horse-power at the drawbar upon the consumption of but a trifle more than two pounds of coal per hour, the discussion of this paper should excite more than ordinary interest.

In the upbuilding process toward a higher plane of excellence of the steam locomotive, the Association has for its future work the further development of the stoker, the superheater, the compound, and other details standing for lesser economies of operation, and with the end in view that their application may become general in character, the working out of a better system of statistics which will show us where we stand and put us in possession of the business facts concerning our department, making them immediately available.

For the department as a whole, the Association has for future work: Organization, as it applies to modern shops and enginehouses; up-to-date apprenticeship systems, applicable to large corporations; development of motor cars for light passenger service; establishment of a bureau for scientific research work.

In connection with the latter recommendation, this Association should make provision for a bureau with a salaried official at its head, to whom research work of a scientific character required of committees can be referred, through the Executive Committee. This would add value to reports and would relieve members of committees of a large amount of detail work to which they can not always devote the time necessary for a thorough investigation of the subject.

The time is past when a motive power officer should be merely a good mechanic and manager of men. He must have these attributes and much more also. He is called upon to-day to be a mechanical engineer, in the design of locomotives; an executive, in the management of a great department; an organizer, in the building up of the department, keeping it abreast of the increasing difficulties of the problems; he must be a business man, in knowing the costs of his work, and in making every dollar of the stockholders' money bring the greatest returns; he must be a diplomat in dealing with other officials, and a general in managing his subordinate officials and his men. These qualifications a man must possess in order to be an important official in any large industrial organization, but in a motive power position additional qualifications are required, which are best summed up in the statement that he must be a railroad man, ready for any and every emergency and ready to fit his work into that of others in such a way as to complete an exceedingly important corner of the organization.

In fitting our work into that of the operating department lies an opportunity, which is perhaps our greatest opportunity of the present time. Up to a certain point we can go with our own office, and up to a certain point we may introduce improvements; but beyond that point we can not go without the heartiest coöperation of others. And it is in the direction of securing this coöperation, or in applying the operating possibilities of our positions, that our greatest future lies. That the operating officers

shall consider the motive power men as their strongest supporters and most helpful allies in the difficulties of their work should be our aim, and in this direction the motive power department can undoubtedly go much farther than it has ever gone, and it is to the importance of this that I direct your attention most earnestly.

We should contribute to secure mileage for our engines, always bearing in mind the fact that locomotives are not intended to make good repair records so much as to pile up ton-mileage. If the ton-mileage is not always obtained, the railroad machine is not working to its best advantage and there may be good reasons for this. By helping the operating official we may find that he can help us, and in the development which tends toward the most favorable operating service lies our greatest work for the future.

Let us remember that we are not merely heads of departments. We are officials of railroads striving to increase to the utmost the net earnings, and when we have gone to the limits of our ability as mechanical men we have yet a long way to go in the direction of the operating men to improve the results. By always conducting our departments so that the motive power is ready for any emergency we shall help the department, help the other officials, and incidentally help ourselves. There is more before us than there is behind us in the way of improvements, and there is no work to-day lying before any class of men which is more important and more inspiring than that in which we are engaged.

[Applause.]

THE PRESIDENT: We will take an intermission of five minutes to allow the visitors to retire who desire to do so.

[After recess.]

The following members registered:

Adams, T. E.
Addis, J. W.
Albright, J. S.
Aldcorn, Thos.
Alter, Wm.
Allan, Arthur.
Allen, C. W.
Allen, G. S.
Amann, W. E.
Anthony, F. S.
Appler, A. B.
Arp, W. C.
Baker, C. F.
Ball, H. F.
Barnes, P. H.
Barrett, C. D.
Bartlett, Henry.
Barton, T. F.
Basford, G. M.
Bentley, H. T.
Best, J. I.
Billingham, R. A.
Bingaman, C. A.
Boler, W. L.
Booth, J. S.
Bowles, C. K.
Bradeen, J. O.
Bradley, W. F.
Brazier, F. W.
Bronner, E. D.
Brown, David.
Brown, T. R.
Brown, W. A.
Bruck, Henry T.
Bryan, H. L.
Buchanan, A. Jr.
Buchanan, W. J.
Bush, S. P.

Bussing, G. H.
Butcher, G. W.

Carson, G. E.
Carson, H. M.
Casey, Fred A.
Cassidy, D. E.
Cory, C. H.
Chamberlain, J. T.
Chambers, J. S.
Chester, W. E.
Chisholm, J. E.
Christopher, J.
Coutant, M. R.
Cromwell, O. C.
Cole, T. J.
Cleaver, F. C.
Clark, F. H.
Clark, Jas.
Cockfield, W.
Collins, W. H.
Connors, J. J.
Cook, J. S.
Cota, A. J.
Cowen, J. H.
Crawford, D. F.
Cromwell, S. A.
Cross, C. W.
Cunningham, D. W.
Cunningham, J. S.
Curry, H. M.
Curtis, T. H.

Davies, M. R.
Davis, D. E.
Davis, E. E.
Deems, J. F.
Deeter, D. H.
Delaney, H.
Depue, Geo. T.
Desmond, D. G.
Dewey, J. J.
Dickson, Geo.
Dillon, S. J.
Diven, J. B.
Doebler, C. H.
Dunham, W. E.
Durrell, D. J.

Edmonds, G. S.
Edmondson, W. G.
Ellis, J. J.
Elordi, Manuel.
Ettenger, R. L.

Feeley, T. M.
Ferguson, G. A.
Ferguson, G. M.
Ferguson, L. B.
Fildes, Thos.
Fitzgerald, W. T.
Flavin, J. T.
Flory, B. P.
Fogg, J. W.
Forsyth, Wm.
Fowler, G. L.
Fowler, W. E.
Fries, A. J.
Fuller, C. E.

Gaines, F. F.
Gallagher, G. A.
Garstang, Wm.
Gentry, T. W.
Gibbs, A. W.
Gibbs, Geo.
Gilbert, E. A.
Gilbert, E. B.
Gilbert, F. M.
Gill, John.
Gillis, H. A.
Girten, W. F.
Goodrich, Max
Gordon, H. D.
Goss, W. F. M.
Gould, J. E.
Graham, Chas.
Gray, G. M.
Greenwood, B. E.
Grieves, E. W.

Hill, John.
Hainen, J.
Hair, John.
Hall, Grant
Hammett, P. M.
Hammond, G. O.
Hancock, Geo. A.
Harrington, H. H.
Harris, Jos. D.
Harrison, F. J.
Haselton, G. H.
Haskell, B.
Hawkins, B. H.
Hayes, J. T.
Haynen, W. J.
Hedley, Frank.
Henderson, G. R.
Herr, E. M.
Howard, J.
Hufsmith, F.
Howard, G. H.
Hibbard, H. Wade.
Hickey, P. J.
Hicks, I. C.
Hill, Rufus.
Hill, W. H.
Hinckley, A. C.
Hindman, S. M.
Hitt, Rodney.
Hobson, W. P.
Hodgins, Geo. S.
Hoffman, R. F.
Hogan, C. H
Holtz, David.
Horsey, A. W.
Horrigan, P. J.
Howard, C. H.
Hubbell, Ira C.
Hudson, W. H.
Hufman, W. H.
Humphrey, A. L.
Hunt, H. B.
Hunter, H. S.
Hyndman, F. T.

Irwin, J. E.

James, E. T.
James, J. M.
Johnson, L. T.
Joughins, G. R.

Kalbaugh, I. N.
Kapp, W. F.
Kearney, Alex.
Keegan, J. E.
Kellogg, W. L.
Kelly, J. W.
Kendig, R. B.
Kilpatrick, J. B.
Kilpatrick, R. F.
Kinney, W. H.
Kneass, S. L.
Kyle, C.

Lane, F. W.
Lanza, G.
Lawes, T. A.
Leach, H. L.
Leach, W. B.
Lewis, H. L.
Lindstrom, C. A.
Lockwood, B. D.
Lonergan, P. T.
Lowry, W. D.

MacBain, D. R.
Mackenzie, John.
Magarvey, J. R.
Maher, P.
Mallory, E. A.
Malthaner, W.
Manchester, H. C.
Manning J. H.
Mannion, T. D.
Marshall, E. S.
Marshall, E. S.
Marshall, W. H.
Maver, A. A.
Maysilles, J. H.
McArthur, F. A.
McCarthy, M. J.
McCarty, H. C.
McCuen, J. P.
McFeatters, F. R.
McHaffie, A. B.
McIntosh, W.
McKee, G. S.
McKeen, W. R. Jr.
McNaughton, Jas.
McRae, J. A.
Medway, John.
Mellin, C. J.
Mendenhall, C. M.
Menzel, W. G.
Michael, J. B.
Miller, E. A.
Miller, E. T.
Miller, Geo. A.
Miller, S. W.
Milliken, Jas.
Minshull, P. H.
Mitchell, A. E.
Monahan, J. J.
Montgomery, Wm.
Moore, J. H.
Moore, J. G.
Morse, C. S.
Mowery, J. N.
Mudd, G. W.
Muhlfeld, J. E.

Nelson, E. D.
Neubert, G. T.
Neuffer, J. G.
Neward, F. H.
Noble, L. C.
Nuttall, W. H.

O'Hearne, J. E.
Orchard, J. H.
Ord, C. R.

Park, S. T.
Parker, M. B.
Parks, Geo. E.
Passmore, H. E.
Patterson, J. S.
Pearse, J. S.
Pearson, W. H.
Peck, P. H.
Pennington, J. H.
Perine, D. M.
Perry, W.
Pettis, C. D.
Pflager, H. M.
Pilcher, J. A.
Platt, J. G.
Player, John.
Pomeroy, L. R.
Poole, A. J.
Potton, J.
Pratt, E. W.
Prendergast, J. F.
Preston, P.
Purves, T. B.

Quereau, C. H.

Raidler, W. P.
Redding, D. J.
Reid, W. L.
Rhodes, L. B.
Richmond, W. H.
Riley, Geo. N.
Robb, W. D.
Robider, W. J.
Robinson, Frank.
Rommel, Geo.
Roope, Thos.
Rosing, W. H. V.
Rumney, T.

Scheffer, F. H.
Schlafge, Wm.
Schmall, G. A.
Sedgwick, E. V.
Seley, C. A.
Setchel, J. H.
Shackford, J. M.
Sheahan, J. F.
Shearman, C. S.
Shepard, L. A.

Shields, C. F.
Shields, H. C.
Shoemaker, H.
Simons, J. E.
Sinclair, A.
Sinnott, Wm.
Skinner, J. R.
Slater, F.
Slayton, C. E.
Smyth, C. B.
Smith, D. A.
Smith, E. O.
Smith, G. W.
Smith, R. D.
Smith, W. A.
Smith, Wm.
Smock, F. A.
Spoor, C. E.
Squire, W. C.
Stansbury, C. M.
Stewart, A. E.
Stewart, C. J.
Stewart, O.
Stewart, T. R.
Stocks, W. H.
Street, C. F.
Sumner, E.
Suzuki, S.
Sweeley, G. P.
Swoyer, H.
Symington, T. H.

Tawse, Robt.
Taylor, C. M.
Taylor, H. D.
Taylor, J. W.
Taylor, W. H.
Teat, W. F.
Terrell, C. H.
Terrell, C. H.
Tewkesbury, E. M.
Thomas, F. H.
Thomas, H. T.
Thomas, I. B.
Thomas, P. G.
Thomas, W. H.
Thomas, W. J.
Thompson, W. O.
Todd, W. W.
Tonge, John.
Tracy, W. L.
Traver, W. H.
Tuma, Frank.
Turner, Amos.
Turner, J. S.
Turner, L. H.
Turnbull, A. G.
Turtle, J. A.

Van Alstyne, David.
Van Doren, G. L.
Vaughan, H. H.
Vernet, C. C.

Wagstaff, Geo.
Waitt, A. M.
Wallace, W. G.
Walton, E. A.
Walsh, F. O.
Walsh, J. F.
Warren, W. B.
Watson, S.
Watters, J. H.
Watts, A. H.
Watts, H. W.
Weisgerber, E. L.
West, G. W.
White, A. M.
White, W.
Whyte, F. M.
Wickhorst, M. H.
Wildin, G. W.
Williams, C. R.
Williams, E. A.
Williams, R. B.
Wilson, W. H.
Wirt, G.
Wright, R. V.

Yergens, W. F.
Yergy, J. P.
Young, J. P.
Young, R. R.

Zerbee, F. J.

THE PRESIDENT: The next order is action on the minutes of the last meeting.

MR. PETER H. PECK (C. & W. I.): I move, Mr. President, that the minutes be accepted as printed. (The motion was carried.)

THE PRESIDENT: The next in order is the reading of the report of the Secretary and Treasurer.

Secretary Taylor read the reports.

To the President and Executive Committee of the American Railway Master Mechanics' Association:

In accordance with the usual custom at our annual Convention, I append herewith statement showing the membership of the Association, and receipts and expenditures during the year just closed.

ACTIVE MEMBERSHIP.

Membership June, 1905		738
Transferred to honorary membership	2	
Deaths	10	
Resignations	8	
Dropped, non-payment of dues and mail returned	31	51
		687
New members during the year		89
Reinstated		1
Total membership		777

ASSOCIATE MEMBERSHIP.

Membership June, 1905	17

HONORARY MEMBERSHIP.

Membership June, 1905	38
Transferred from active	2
Total	40

TOTAL MEMBERS.

Active	777
Associate	17
Honorary	40
	834

At the convention of 1905 Messrs. G. W. Rhodes and Charles H. Cory were transferred to honorary membership.

During the year the following resignations were received:

Active members: George S. Mackinnon, W. S. Templeton, F. W. Morse, O. T. Forbes, Arthur Dinan, Lester I. Knapp, W. K. Christie, N. W. Norsworthy.

The following deaths have been recorded:

John Taylor, A. Sauter, L. M. Butler, J. W. Philbrick, J. M. Davies, W. P. Appleyard, A. J. Pitkin, George W. Cushing, John C. Hayden, F. N. Risteen.

The following names have been taken from the list of members because of non-payment of dues, or on account of their mail being returned:

W. L. Calvert, J. J. Tomlinson, Henry W. Arnold, L. H. Bryan, James Carr, D. C. Courtney, J. A. Edwards, F. W. Fritchey, A. W. Harned, A. B. Heers, William Jenkins, J. B. Johnson, H. P. Knight, William M. Cummer, John Lahey, W. O. Lucas, B. F. Marshall, A. Moraga, W. P. Orland, Eli Punshon, S. R. Richards, Mason Rickert, Frank Robinson, A. N. Sanborn, George C. Smith, George W. Tompkins, J. M. Wallis, F. V. Webb, A. L. Weisgerber, A. T. West, A. B. Withers.

The following is a list of members added to the roll during the year:

F. M. Gilbert, M. E., N. Y. C. & H. R. R. R. Co., New York, N. Y.

D. G. Desmond, M. M., Morgantown & Kingwood, R. R., Morgantown, W. Va.

B. D. Lockwood, M. E., C. C. C. & St. L. Ry., Indianapolis, Ind.

W. F. Kaderly, M. M., Southern Ry., Alexandria, Va.

S. J. Delaney, M. M., N. Y. C. & H. R. R. R., New York, N. Y.

Georges Collin, Engr. Machy., Northern Ry. of France, Paris, France.

W. H. Kinney, Gen. Foreman, N. Y. O. & W. Ry., Carbondale, Pa.

F. M. McNulty, M. M., Monongahela Connecting R. R., Pittsburg, Pa.

L. B. Ferguson, M. M., Vicksburg, Shreveport & Pacific Ry., Monroe, La.

Max Goodrich, M. M., New York & Ottawa R. R., Ottawa, Ont., Can.

John R. Magarvey, Supt., American Locomotive Co., Dunkirk, N. Y.

Georges Asselin, Principal Engr. M. P., Northern Ry. of France, Paris, France.

J. A. McRae, M. E., Boston & Albany R. R., Albany, Mass.

R. J. Goodale, M. M., Illinois Central R. R., Centralia, Ill.

F. B. Barclay, M. M., Ill. Cent. R. R., Memphis, Tenn.

George H. Gilman, Shop Supt., Northern Pac. Ry., St. Paul, Minn.

C. D. Vanaman, M. M., Florida East Coast Ry., St. Augustine, Fla.

Jos. Chidley, Asst. M. M., L. S. & M. S. Ry., Elkhart, Ind.

J. F. Enright, M. M., Mobile & Ohio R. R., Whistler, Ala.

A. B. Adams, G. F., C. & N.-W. Ry., Huron, S. D.

D. F. Van Ripper, G. F., Erie Railroad, Meadville, Pa.

R. R. Young, M. M., Atlantic Coast Line R. R., Waycross, Ga.

J. W. Oplinger, S. M. P., Atlantic Coast Line Ry., Savannah, Ga.

C. L. Meister, M. E., Atlantic Coast Line Ry., Wilmington, N. C.

G. R. Joughins, Intercolonial Ry., Moncton, N. B.

T. D. Mannion, M. M., Phila. & Reading Ry., Camden, N. J.

D. H. Deeter, M. M., Phila. & Reading Ry., Reading, Pa.

H. S. Hunter, M. M., Phila. & Reading Ry., Philadelphia, Pa.

Theo. Laurent, Asst. C. E., Paris & Orleans Ry., Paris, France.

H. B. Brown, M. M., Erie Railroad, Cleveland, O.

M. J. McCarthy, M. M., Michigan Central Ry., St. Thomas, Can.

H. B. Howe, Gen. Wks. Mngr., New South Wales Rys., Sydney, Australia.

John Wahlen, M. M., Montpelier & Wells River R. R., Montpelier, Vt.

William E. George, Commissioner of Rys., Western Australia Rys., Perth, Australia.

E. S. Hume, C. M. E., Western Australian Govt. Rys., Freemantle, Australia.

J. H. McGoff, M. M., A. T. & S. F. Ry., Ft. Madison, Iowa.

D. J. Mullen, M. M., C. C. C. & St. L. Ry., Mt. Carmel, Ill.

D. W. Ford, M. M., Pacific Coast Ry., San Luis Obispo, Cal.

C. H. Temple, M. M., Can. Pac. Ry., Winnipeg, Man.

H. W. Burkheimer, M. M., Southern Ry., Charleston, S. C.

John Dickson, M. M., Great Northern Ry., Grand Forks, N. D.

V. N. Powell, M. M., Ill. Cent. R. R., Mattoon, Ill.

J. Cardell, M. M., Canadian Pacific Ry., Calgary, Alberta, Can.

W. M. Taylor, M. M., Thornton & Alexandria Ry., Thornton, Ark.

H. Green, M. E., So. Balt. Steel Car & Fdry. Co., Baltimore, Md.

William J. Haynen, M. M., Detroit, Toledo & Ironton Ry., Springfield, O.

Max H. Wickhorst, Engr. of Tests, C. B. & Q. Ry., Aurora, Ill.

E. D. Nelson, Engr. Tests, Penna. R. R., Altoona, Pa.

Fred Bather, Mech. Foreman, Mexican International R. R., Torreon, Coahuila, Mex.

John Mailer, M. M., Ft. Smith & Western R. R., Ft. Smith, Ark.

George R. Bennett, Gen. Foreman, Mobile & Ohio R. R., Whistler, Ala.

M. C. Dinkel, S. M. P. & M., Ixtlahuaca, Mani & Nijini Ry., Ixtlahuaca, Mexico.

William H. Murray, M. M., Cin., Ham. & Dayton Ry., Cincinnati, O.

R. M. McDougall, M. M., Morenci & Southern Ry., Morenci, Ariz.

John W. Harkom, Gen. Supt., Canadian Fdry. Co., Toronto, Ont., Can.

G. O. Hammond, Mech. Engr., Erie R. R., Meadville, Pa.

W. G. Edmondson, Engr. of Tests, Phila. & Reading Ry., Reading, Pa.

L. L. Bentley, M. E., Lehigh Valley R. R., South Bethlehem, Pa.

I. C. Hicks, M. M., A. T. & S. F. Ry., Albuquerque, N. M.

W. H. Collins, M. M., Fonda, Johnstown & Gloversville Ry., Gloversville, N. Y.

Charles T. Noyes, Supt. Shops, Southern Pac. Co., Sacramento, Cal.

J. S. Albright, M. M., Mexican National R. R., San Luis Potosi, Mex.

John McManamy, A. M. M., P. M. R. R., St. Thomas, Ont., Can.

G. H. Bussing, S. M. P. & R. S., Evansville & Terre Haute Ry., Evansville, Ind.

W. C. Burel, M. M., Trinity & Brazos Valley Ry., Cleburne, Tex.

W. J. Shreeve, M. M., Minneapolis & Rainy River Ry., Deer River, Minn.

C. J. Stewart, M. M., Cent. New England R. R., Hartford, Conn.

T. Sakuma, S. M. P., Kinshiu Ry., Moji, Japan.

B. H. Gray, M. M., New Orleans Terminal R. R., New Orleans, La.

John T. Hayes, M. M., Grand Rapids & Ind. Ry., Grand Rapids, Mich.

E. G. Bryant, D. M. M., International & Great Northern R. R., Mart, Tex.

Marcel Japiot, A. S. M. P., French State Rys., Dijon, France.

Octave Henry Greard, A. S. M. P., French State Rys., Paris, France.

J. N. Mowery, M. E., Lehigh Valley R. R., So. Bethlehem, Pa.

A. Bardsley, M. M., Gulf & Ship Island Ry., Gulfport, Miss.

C. M. Hoffman, M. M., Southern Ry., Princeton, Ind.

J. B. Elliott, G. M. M., Can. Pac. Ry., Montreal, Can.

J. E. Chisholm, G. M. M., Chicago Great Western Ry., Oelwein, Ia.

Manuel Elordi, Gen. Inspr., Mach. & Loco. Purchases, Argentine Gov't.

D. E. Davis, M. M., Boston & Maine R. R., Concord, N. H.

H. H. Hale, A. M. M., Pere Marquette R. R., Grand Rapids, Mich.

D. J. Durrell, Asst. Engr. M. P., P. C. C. & St. L. Ry., Columbus, O.

S. J. Hungerford, Supt. Loco. Wks., Can. Pac. Ry., Winnipeg, Man.

William Miller, M. M., Denver & Rio Grande Ry., Denver, Colo.

F. P. Roesch, M. M., Southern Ry., Birmingham, Ala.

H. P. Durham, S. M. P. & M., Tehuantepec National R. R., Rincon, Antonio (Oaxaca, Mex.).

J. A. Turtle, M. M., Union Pac. Ry., Denver, Colo.

S. Phipps, M. M., Can. Pac. Ry., Revelstroke, B. C.

C. G. Arthur, M. M., Southern Ry., Columbia, S. C.

REINSTATED.

N. Frey, M. M., Chicago, Bur. & Northern R. R., La Crosse, Wis.

The receipts and expenditures during the year ending June 4th, the date when the books were closed preparatory to this report, were as follows:

RECEIPTS.

To dues collected from members	$3,675.00
" sale of Proceedings	1,080.56
" Ryerson scholarship fund	600.00
" bank balance	1.89
" incidentals	5.25
	$5,362.70

EXPENSES.

Paid exchange	$ 21.60
" expenses Convention, 1905	57.40
" stamps and stamped envelopes	291.83
" office supplies	61.83
" printing	2,187.53
" telegrams	1.38
Carried forward	$2,621.57

Brought forward	$2,621.57
Paid expenses, committees	77.50
" express	114.28
" blue-prints, tracings, etc	49.40
" salary, Secretary, including clerk	1,200.00
" reporting Convention, 1905	163.15
" Ryerson scholarship	600.00
" office rent	199.94
" surety bond, Secretary	6.80
" zinc cuts, etc.	34.35
" telephone service	35.00
Balance, remitted to Treasurer	260.71
Total	$5,362.70

The bills against the Association have been paid except for the preparation of three of four of the reports which were printed after the books were closed.

The unpaid dues amount to $785.

A statement showing the members in arrears for dues and the amount thereof is presented herewith for the information of the members.

A detailed statement of the dues collected during the year is herewith appended and made part of the report.

At the last convention the Secretary reported that he had in a special fund the sum of $3,077.44 for the use of the Committee on Locomotive Front Ends. During the year there has accrued interest amounting to $20,35, so that the total fund available during the year for this purpose amounted to $3,097.79.

The committee has been actively engaged during the year and has concluded the investigation, and its report will be read to you in the regular order of business. The fund at the disposal of the committee has been entirely expended, as will be seen by the following statement:

RECEIPTS.

Balance on hand last report	$3,037.41
Received contribution	30.00
Returned from Purdue University	54.52
Interest on bank balance	30.38
Total	$3,152.31

EXPENSES.

Advanced to Purdue University account of committee.	$2,850.00
Paid preparation and distribution of committee's report	302.31
Total	$3,152.31

Vouchers Nos. 1 to 8 are appended herewith to show the expenditures.

SCHOLARSHIPS.

The scholarships at Stevens Institute still continue to be filled. It is hoped before the convention is over to advise the members as to whether any vacancies will exist as a result of the June examinations.

The reports from Purdue University as to the young man who is holding the Ryerson scholarship are of a most excellent character. The young man is reported as standing very high in his classes and to be a man of excellent deportment, and altogether a great credit to the donors of the fund and to the Association.

DETAILED STATEMENT OF DUES COLLECTED FROM MEMBERS.

1905.		
June 15	G. S. Allen.....$	5.00
" 15	F. S. Anthony..	5.00
" 15	W. C. Arp.....	5.00
" 15	G. H. Baker....	5.00
" 15	T. F. Barton....	5.00
" 15	Jos. Billingham.	10.00
" 15	J. R. Bissett....	5.00
" 15	J. O. Bradeen...	5.00
" 15	David Brown...	5.00
" 15	W. A. Brown...	5.00
" 15	B. B. Cargo....	5.00
" 15	C. E. Chambers.	5.00
" 15	F. C. Cleaver...	5.00
" 15	W. Cross	5.00
" 15	H. Delaney	5.00
" 15	W. H. Dooley..	5.00
" 15	T. M. Downing.	5.00
" 15	R. L. Ettinger..	5.00
" 15	J. F. Enright...	5.00
" 15	T. M. Feeley...	10.00
" 15	J. H. Fildes....	5.00
" 15	Thos. Fildes ...	5.00
" 15	Jno. Forster ...	5.00
" 15	A. J. Fries.....	5.00
" 15	Jno. Gill	5.00
" 15	B. E. Greenwood	5.00
" 15	John Hainen ..	5.00
" 15	C. S. Hall.....	5.00
" 15	F. J. Harrison..	10.00
Carried forward .....$		160.00

Brought forward .....$		160.00
June 15	G. H. Haselton.	5.00
" 15	B. Haskell	5.00
" 15	P. J. Hickey...	10.00
" 15	Rufus Hill	5.00
" 15	W. H. Hill.....	5.00
" 15	C. H. Hogan...	5.00
" 15	John Howard..	5.00
" 15	F. T. Hyndman.	5.00
" 15	John A. Hill...	5.00
" 15	O. H. Jackson..	5.00
" 15	Willard Kells ..	5.00
" 15	J. B. Kilpatrick.	5.00
" 15	R. F. Kilpatrick	5.00
" 15	C. Kyle	5.00
" 15	C. F. Lape.....	10.00
" 15	P. T. Lonergan.	5.00
" 15	M. J. Lynn.....	5.00
" 15	John Mackenzie.	5.00
" 15	W. Malthaner ..	10.00
" 15	G. A. Miller....	5.00
" 15	S. W. Miller...	5.00
" 15	P. H. Minshull.	5.00
" 15	C. M. Muchnic.	5.00
" 15	J. H. Murphy..	5.00
" 15	F. H. Neward..	10.00
" 15	J. E. O'Hearne.	5.00
" 15	J. W. Oplinger.	5.00
" 15	P. H. Peck.....	5.00
" 15	C. Phillips	5.00
Carried forward .....$		325.00

	Brought forward	$	325.00
June	15	Robt. Preston..	5.00
"	15	C. H. Quereau..	5.00
"	15	O. H. Reynolds.	5.00
"	15	G. W. Smith...	5.00
"	15	L. A. Shepard..	5.00
"	15	H. Shoemaker..	5.00
"	15	D. A. Smith....	5.00
"	15	F. B. Smith....	5.00
"	15	F. C. Smith....	5.00
"	15	O. Stewart	5.00
"	15	E. T. Sumner..	5.00
"	15	W. E. Symons..	5.00
"	15	H. Tandy	5.00
"	15	J. J. Thomas, Jr.	10.00
"	15	W. T. Thompson	5.00
"	15	L. C. Todd.....	5.00
"	15	John Tonge ...	5.00
"	15	C. E. Turner...	5.00
"	15	J. S. Turner....	5.00
"	15	G. L. VanDoren	5.00
"	15	Geo. Wagstaff..	5.00
"	15	W. G. Wallace.	5.00
"	15	A. H. Watts...	5.00
"	15	John Whetstone	5.00
"	15	A. M. White...	5.00
"	15	G. Wirt	5.00
"	15	T. W. Gentry..	20.00
"	15	W. H. Thomas.	5.00
"	15	S. J. Delaney...	5.00
"	15	Geo. Collin	5.00
"	15	W. H. Kinney..	5.00
"	15	Max Goodrich .	5.00
"	15	Geo. Asselin ...	5.00
"	15	C. D. Vanaman.	5.00
"	15	A. B. McHaffie.	5.00
"	15	T. D. Mannion.	5.00
"	15	D. H. Deeter...	5.00
"	15	H. S. Hunter..	5.00
"	15	Theo. Laurent .	5.00
"	15	H. B. Brown...	5.00
"	15	M. J. McCarthy	5.00
"	15	John Wahlen...	5.00
"	15	Wm. E. George.	5.00
	Carried forward	$	560.00

	Brought forward	$	560.00
June	15	E. S. Hume....	5.00
"	27	G. S. Mackinnon	10.00
"	27	Patrick Ryan ..	5.00
"	27	M. S. Curley...	5.00
"	27	T. M. Gibb.....	5.00
"	27	F. W. Lane.....	5.00
"	27	N. L. Smitham.	10.00
"	27	W. R. Deeble...	10.00
"	27	John Neville ...	5.00
"	27	G. A. Gallagher.	5.00
"	27	F. P. Hickey...	5.00
"	27	John Hawthorne	5.00
"	27	W. C. Ennis.	5.00
"	27	Fred F. Hildreth	5.00
"	27	W. Montgomery	5.00
"	27	C. W. Lee.....	5.00
"	27	T. M. Feeley...	10.00
"	27	J. H. McGoff...	5.00
"	15	Geo. Dickson...	5.00
"	27	D. J. Mullen...	5.00
"	27	S. Suzuki	5.00
"	27	H. T. Bruck...	10.00
"	27	N. Frey	15.00
"	27	D. W. Ford....	5.00
"	29	C. J. Bushmeyer	5.00
"	29	S. F. Forbes...	5.00
July	5	G. W. Cushing..	5.00
"	6	W. L. Reid.....	5.00
"	6	J. F. Walsh....	5.00
"	6	Beriah Warren .	5.00
"	6	W. B. Warren.	5.00
"	6	W. H. Hufman.	5.00
"	6	L. H. Turner...	5.00
"	6	W. S. Morris..	5.00
"	6	R. J. Gross.....	5.00
"	6	C. E. Fuller....	5.00
"	6	W. A. Smith...	5.00
"	6	Geo. R. Henderson	5.00
"	6	N. W. Sample..	10.00
"	6	T. M. Markle..	5.00
"	6	Jesse Gauthier..	5.00
"	6	F. H. Clark....	5.00
	Carried forward	$	810.00

Brought forward			$ 810.00
July	6	L. C. Noble....	5.00
"	6	M. J. Drury....	5.00
"	6	J. G. Neuffer...	5.00
"	6	Robt. Quayle ..	5.00
"	6	J. B. Barnes....	5.00
"	6	H. F. Ball.....	5.00
"	6	P. G. Baker....	5.00
"	6	Sam'l Watson..	5.00
"	6	C. H. Howard..	5.00
"	6	J. E. Keegan...	5.00
"	6	Wm. Garstang..	5.00
"	6	E. S. Marshall.	5.00
"	6	Robt. Moran...	5.00
"	6	W. H. V. Rosing	5.00
"	6	W. A. Nettleton	5.00
"	6	C. A. Seley.....	5.00
"	6	F. D. Casanave.	5.00
"	6	Thos. Coyle ...	5.00
"	6	H. B. Ayers....	5.00
"	6	Geo. W. Wildin.	5.00
"	6	Sam'l Higgins..	5.00
"	6	Lester I. Knapp	5.00
"	6	Geo. E. Parks..	5.00
"	6	Geo. W. West..	5.00
"	5	W. H. Taylor..	5.00
"	15	W. C. Ennis....	5.00
"	6	Philip Wallace..	5.00
"	6	R. C. Cumback.	5.00
"	6	E. A. Walton...	5.00
"	6	F. Hedley	5.00
"	6	F. W. Brazier..	5.00
"	6	S. L. Kneas....	5.00
"	6	I. N. Wilber...	5.00
"	6	G. Lanza	5.00
"	6	E. E. Davis ...	5.00
"	6	Thos. Aldcorn .	10.00
"	6	J. J. Sullivan...	5.00
"	6	Geo. L. Dickson	5.00
"	6	J. H. Watters..	5.00
"	6	J. A. Carney....	5.00
"	6	A. E. Mitchell..	5.00
"	6	H. Monkhouse .	5.00
"	6	S. F. Prince, Jr.	5.00
Carried forward			$1,030.00

Brought forward			$1,030.00
July	6	H. H. Vaughan.	5.00
"	6	A. M. Waitt....	5.00
"	6	W. P. Appleyard	5.00
"	7	L. R. Pomeroy.	5.00
"	7	J. F. Deems....	5.00
"	7	W. K. Nuttall..	5.00
"	7	J. R. Magarvey.	5.00
"	7	G. K. Hatz.....	5.00
"	7	Fred B. Griffith	10.00
"	7	J. H. Pennington	5.00
"	7	Wm. Buchanan.	5.00
"	7	E. P. Mallinson	5.00
"	7	J. H. Manning.	5.00
"	7	W. E. Dunham.	5.00
"	7	Geo. N. Riley...	5.00
"	7	W. O. Thompson	5.00
"	10	Henry Bartlett .	5.00
"	10	A. J. Dunn.....	5.00
"	10	A. J. Pitkin....	5.00
"	10	J. W. Marden..	5.00
"	10	Chas. H. Davis.	5.00
"	10	Amos Turner..	5.00
"	10	E. W. Pratt....	5.00
"	10	D. J. Justice...	5.00
"	10	J. H. Clark.....	5.00
"	10	W. H. Wilson..	5.00
"	10	Wm. Fuller ...	5.00
"	10	K. P. Alexander	5.00
"	10	J. E. Sague.....	5.00
"	10	E. J. Smith....	5.00
"	10	C. H. Welch...	5.00
"	10	W. W. Atterbury	5.00
"	10	H. M. Pflager..	5.00
"	10	S. K. Dickerson	5.00
"	10	J. A. Graham..	5.00
"	10	W. E. Chester.	5.00
"	10	Edw. C. Bates..	5.00
"	10	W. T. Smith...	5.00
"	10	W. G. Menzel..	5.00
"	10	D. O'Leary....	5.00
"	10	A. C. Adams...	5.00
"	10	F. H. Scheffer.	5.00
"	10	C. F. Jones....	5.00
Carried forward			$1,250.00

	Brought forward		$1,250.00
July	10	F. A. Delano...	5.00
"	10	W. F. M. Goss.	5.00
"	17	Le Grand Parish	5.00
"	17	W. S. Hancock.	5.00
"	17	W. J. McLean.	5.00
"	17	Thos. Millen...	5.00
"	17	Tracy Lyon ...	5.00
"	17	R. E. McCuen..	5.00
"	17	F. M. Whyte...	5.00
"	17	F. M. Gilbert..	5.00
"	17	W. B. Leach...	5.00
"	17	J. F. Fleischer.	5.00
"	17	E. Dawson.....	10.00
"	17	T. W. Macfarlane	5.00
"	17	R. H. Soule....	5.00
"	17	E. T. James....	5.00
"	17	C. E. Rettew...	5.00
"	17	D. A. Wightman	5.00
"	17	H. S. Hayward	5.00
"	17	R. A. Billingham	5.00
"	17	John A. Pilcher	5.00
"	17	John C. Glass..	5.00
"	17	F. B. Barclay..	5.00
"	17	Max Toltz	5.00
"	17	W. H. Stocks..	5.00
"	17	E. T. White ...	5.00
"	17	Wm. O'Herin .	5.00
"	17	W. L. Austin..	5.00
"	17	S. M. Vauclain.	5.00
"	17	A. B. Johnson..	5.00
"	17	John McGie ...	5.00
"	17	H. L. Leach...	5.00
"	17	John C. Homer.	5.00
"	17	E. M. Herr....	5.00
"	17	E. J. Smith....	5.00
"	17	J. J. Casey.....	5.00
"	17	I. N. Kalbaugh.	5.00
"	17	Jas. A. Egan...	5.00
"	17	Geo. Hodgins ..	5.00
"	17	H. T. Thomas..	5.00
"	17	E. F. Needham.	5.00
	Carried forward		$1,460.00

	Brought forward		$1,460.00
July	17	E. D. Bronner..	5.00
"	17	Henry Elliott ..	5.00
"	17	J. P. McCuen..	5.00
"	17	C. L. Meister..	5.00
"	17	M. Dunn	5.00
"	17	T. A. Brown...	5.00
"	17	A. Stewart	5.00
"	17	T. E. Keyworth	5.00
"	17	John Hair	5.00
"	17	Truman C. Link	5.00
"	17	J. L. Greatsinger	5.00
"	17	H. A. Gillis ...	5.00
"	17	M. S. Monroe..	5.00
"	17	F. M. Pierce...	5.00
"	17	A. E. Manchester	5.00
"	25	N. L. Smitham.	5.00
"	25	C. R. Ord	5.00
"	25	E. B. Gilbert...	5.00
"	25	M. D. Stewart.	5.00
"	25	W. J. Wilcox..	5.00
"	25	J. A. McRae....	5.00
"	25	Owen Clarke ..	5.00
"	25	Wm. McIntosh.	5.00
"	25	David Van Alstyne	5.00
"	25	R. P. C. Sanderson	5.00
"	25	D. E. Cassidy..	5.00
"	25	Alex B. Todd..	5.00
"	25	Wm. Renshaw..	5.00
"	25	T. E. Adams...	5.00
"	25	Geo. Whale	5.00
"	25	W. C. Hayes...	5.00
"	25	H. J. Small....	5.00
"	25	F. E. Neward..	5.00
"	25	L. B. Ferguson.	5.00
"	25	Harry Ashton .	5.00
"	25	H. N. Breneman	5.00
"	25	R. D. Smith....	5.00
"	25	Wm. Jennings .	5.00
"	25	W. H. Marshall	5.00
"	25	Oscar Antz	5.00
	Carried forward		$1,660.00

Brought forward			$1,660.00
July	25	C. M. Stansbury	5.00
"	25	W. P. Hobson..	5.00
"	25	W. R. McKeen, Jr.	5.00
"	25	J. P. Nolan....	5.00
"	25	C. H. Doebler..	5.00
"	26	Allen Vail	5.00
"	26	J. W. Fogg	5.00
"	26	J. F. Deems....	5.00
"	26	John S. Cook..	5.00
"	26	E. N. Weist ...	5.00
"	26	R. Tawse	5.00
"	26	W. C. Walsh...	5.00
"	26	Geo. James	5.00
"	26	M. Robinson ...	5.00
"	26	D. G. Desmond.	5.00
"	26	A. A. Hube....	5.00
"	26	Jas. McNaughton	5.00
"	26	J. B. McMichael	5.00
"	26	B. P. Flory....	5.00
"	26	D. F. Crawford	5.00
"	26	F. E. Davisson.	5.00
"	26	Wilson Worsdell	5.00
"	27	C. G. Arthur...	5.00
"	27	J. Cardell	5.00
"	27	Jno. Dickson ..	5.00
"	27	H. W. Burkheimer	5.00
Aug.	1	H. C. Van Buskirk	5.00
"	1	W. F. Kapp....	5.00
"	1	P. G. Thomas..	5.00
"	1	E. A. Williams.	5.00
"	1	F. O. Walsh....	5.00
"	1	A. W. Gibbs...	5.00
"	1	A. S. Vogt.....	5.00
"	1	J. J. Conally...	5.00
"	1	J. E. Goodman.	5.00
"	1	T. A. Foque....	5.00
"	1	E. A. Miller....	5.00
"	1	T. W. Demarest	5.00
"	1	I. W. Fowle....	5.00
Carried forward			$1,855.00

Brought forward			$1,855.00
Aug.	1	Bert Hartigan..	5.00
"	1	H. S. Bryan....	5.00
"	1	W. H. Richmond	5.00
"	1	Jos. Chidley ...	5.00
"	1	M. G. Bock	5.00
"	1	W. F. Post	5.00
"	1	John W. Cloud.	5.00
"	1	Thos. Booth ...	5.00
"	1	J. R. Groves ...	5.00
"	1	F. A. Casey	5.00
"	1	P. Maher	5.00
"	1	T. H. Symington	5.00
"	1	F. Mertsheimer.	5.00
"	1	C. M. Babcock.	5.00
"	1	J. K. Brassil...	5.00
"	1	Wm. M. Taylor	5.00
"	1	W. J. Thomas..	10.00
"	1	A. L. Humphrey	5.00
"	1	Jos. E. Gould...	5.00
"	1	Jos. E. Irwin..	5.00
"	1	J. B. Gannon..	5.00
"	1	J. J. Waters...	5.00
"	1	Thos. Paxton ..	5.00
"	1	A. Forsyth	5.00
"	1	F. A. Torrey ...	5.00
"	1	F. R. Cooper...	5.00
"	1	F. A. Chase....	5.00
"	2	Gustav Willius, Jr.	5.00
"	3	C. M. Mendenhall	5.00
"	3	Geo. L. Fowler.	5.00
"	3	G. J. Churchward	5.00
"	3	C. H. Wiggin..	5.00
"	3	J. W. Balderston	5.00
"	8	W. F. Yergens.	5.00
"	8	T. A. Lawes....	5.00
"	8	C. F. Street....	5.00
"	8	C. H. Seabrook.	5.00
"	8	Chas. Wilson ..	5.00
"	8	J. H. Rice.....	5.00
"	8	Willis C. Squire	5.00
Carried forward			$2,060.00

		Brought forward	$2,060.00
Aug.	8	A. B. Adams...	5.00
"	8	R. J. Goodale..	5.00
"	8	David Clark ...	5.00
"	8	T. W. Heintzleman	5.00
"	8	F. Hufsmith ...	5.00
"	8	Luis Greaven ..	5.00
"	8	E. B. Thompson	5.00
"	15	Ben Johnson ..	5.00
"	15	R. H. Briggs...	5.00
"	15	J. S. Chambers.	5.00
"	15	W. E. Amann..	5.00
"	15	W. F. Kaderly.	5.00
"	15	J. J. Ryan.....	5.00
"	15	Mord Roberts..	5.00
"	15	A. J. Cota.....	5.00
"	15	W. H. Traver..	5.00
"	15	J. J. Monahan..	5.00
"	15	F. J. Cole.....	5.00
"	15	G. M. Basford..	5.00
"	15	P. M. Hammett	5.00
"	15	P. H. Murphy..	5.00
"	15	E. Ryan	5.00
"	15	L. B. Rhodes..	5.00
"	15	Fred Bather....	5.00
"	15	Geo. A. Bruce..	5.00
"	15	Geo. Gibbs	5.00
"	15	Wm. Forsyth...	5.00
"	15	John H. Maysilles	5.00
"	17	Angus Sinclair.	5.00
"	17	B. M. Boldridge	15.00
"	17	C. C. Vernet...	10.00
"	17	R. N. Durborow	5.00
"	18	Geo. H. Gilman	5.00
"	24	H. M. Curry....	5.00
"	24	E. Chamberlain.	15.00
"	24	Chas. J. Thornton	5.00
"	24	John J. Ellis...	5.00
"	24	A. L. Studer....	5.00
"	24	G. R. Joughins.	5.00
"	24	H. E. Passmore	5.00
		Carried forward	$2,285.00

		Brought forward	$2,285.00
Aug.	24	John Hopwood.	5.00
"	26	H. H. Kendall..	5.00
"	26	P. H. Reeves...	5.00
"	26	H. B. Kent.....	5.00
"	26	S. B. Clay.....	10.00
"	26	S. F. Forbes...	5.00
"	30	L. S. Kinnaird..	5.00
"	30	F. M. Twombly.	5.00
"	30	J. R. Van Cleve	5.00
"	30	Wm. Allport...	5.00
"	30	J. T. McGrath..	5.00
"	30	C. E. Uddenberg	5.00
"	30	A. H. Gairns...	10.00
"	30	John Waddington	5.00
Sept.	12	J. W. Addis....	5.00
"	12	R. B. Kendig...	5.00
"	12	E. T. Slayton..	5.00
"	12	John Horrigan.	5.00
"	12	Chas. H. Barnes	5.00
"	12	Jas. Macbeth...	5.00
"	12	H. Green	5.00
"	12	G. S. McKee...	5.00
"	12	M. R. Coutant..	5.00
"	12	Robt. Gould ...	5.00
"	12	John S. Booth..	5.00
"	12	S. P. Bush.....	5.00
"	12	C. E. Slayton...	5.00
"	12	Wm. Kelly	5.00
"	12	F. G. Benjamin	5.00
"	12	A. A. Campbell.	5.00
"	12	E. D. Nelson...	5.00
"	12	W. H. Lewis...	5.00
"	12	A. Kearney	5.00
"	12	G. T. Neubert..	5.00
"	12	H. W. English..	5.00
"	12	T. S. Inge.....	5.00
"	14	Wm. Schlafge .	5.00
"	14	Antonio Pinheiro	5.00
"	16	A. L. Beattie...	10.00
"	16	S. C. Graham..	15.00
"	16	H. T. Bentley..	5.00
"	16	W. Sinnott	5.00
		Carried forward	$2,520.00

Brought forward			$2,520.00
Sept.	18	M. Jungling ..	5.00
"	23	C. R. Hillman..	5.00
"	23	M. C. Dinkel...	5.00
"	23	Geo. H. Emerson	5.00
"	23	R. A. Smart ...	5.00
"	23	C. R. Williams.	5.00
"	30	Geo. B. Nutt...	5.00
"	30	Henry Tregelles	5.00
"	30	Geo. R. Bennett	5.00
Oct.	12	F. G. Ferguson.	5.00
"	12	J. E. Cameron.	5.00
"	12	Wm. E. Knight	5.00
"	12	M. H. Wickhorst	5.00
"	12	Geo. Gilmour...	5.00
"	12	A. Lopez Aldana	5.00
"	12	Alfred Lovell...	5.00
"	12	W. D. Holland.	10.00
"	12	C. W. Cross....	5.00
"	12	W. H. Murray.	5.00
Nov.	7	C. A. Ferguson.	5.00
"	7	F. F. Gaines....	5.00
"	7	W. H. Brehm..	5.00
"	7	Arthur Dinan ..	5.00
"	7	W. S. Clarkson.	5.00
"	7	F. C. York.....	10.00
"	7	C. W. Stevenson	5.00
"	7	Jas. Fitzmorris.	5.00
"	7	H. D. Ellis.....	10.00
"	7	W. J. Haynen..	5.00
"	7	W. L. Gilmore.	5.00
"	7	R. R. Young...	5.00
"	7	John Mailer ...	5.00
"	7	J. R. Gould....	5.00
"	7	R. M. McDougall	5.00
"	17	F. M. Fryburg.	5.00
"	14	J. D. Harris....	5.00
"	16	J. B. Morgan...	5.00
"	16	B. H. Hawkins.	5.00
"	16	F. J. Leigh.....	5.00
"	20	Thos. J. Cole...	5.00
"	24	A. Shields	5.00
"	24	L. S. Randolph.	5.00
Carried forward			$2,745.00

Brought forward			$2,745.00
Nov.	24	John W. Harkom	5.00
Dec.	7	Arthur O. Berry	5.00
"	7	R. H. Johnson.	5.00
"	7	Jas. W. Hill....	5.00
"	8	H. C. May.....	10.00
"	16	C. J. Mullin....	5.00
"	27	W. B. Gaskins..	5.00
"	27	W. D. Robb....	5.00
"	27	J. H. McConnell	5.00
"	27	H. Pearse	5.00
"	27	T. S. Beauclerk	5.00
"	27	W. N. Best....	5.00
"	27	A. R. Kipp.....	5.00
"	29	J. B. Miller....	5.00
Jan.	3	A. C. Deverell..	5.00
"	3	Wm. Augustus.	5.00
"	11	Chas. DeGress..	5.00
"	11	C. M. Taylor ..	5.00
"	11	W. J. Tollerton	5.00
"	11	A. J. Cromwell.	5.00
"	18	H. Wade Hibbard	5.00
"	23	L. L. Bentley..	5.00
"	23	L. M. Kidd.....	5.00
"	23	J. A. Gibson....	5.00
Feb.	3	F. H. Litton....	5.00
"	3	W. L. Kellogg..	5.00
"	3	T. J. Cutler....	5.00
"	12	J. S. Patterson.	5.00
"	12	V. Z. Caracristi	5.00
"	12	C. H. Temple..	5.00
"	12	J. G. Beaumont.	5.00
"	14	S. Suzuki	5.00
"	14	W. H. Collins..	5.00
"	14	Chas. T. Noyes.	5.00
"	14	J. S. Albright..	5.00
"	23	John Medway ..	5.00
"	28	J. W. Records..	10.00
Mar.	1	V. B. Lang.....	5.00
"	1	E. Thomas	10.00
"	1	H. G. Bechhold	5.00
"	1	D. R. MacBain.	5.00
"	1	Theo. H. Curtis	5.00
Carried forward			$2,970.00

		Brought forward	$2,970.00
Mar.	2	C. A. Delaney..	5.00
"	2	Wm. Hassman .	5.00
"	2	S. N. Woodruff.	5.00
"	2	Jas. Buchanan..	5.00
"	2	S. T. Park.....	5.00
"	2	T. D. MacDonald	5.00
"	2	W. S. Galloway	5.00
"	2	J. S. Pearce....	5.00
"	3	C. F. Baker....	5.00
"	3	C. G. Turner..	5.00
"	3	C. F. Chase....	5.00
"	3	P. H. Brangs..	5.00
"	3	C. A. Thompson	5.00
"	5	T. McNabb	5.00
"	5	C. B. Royal....	5.00
"	5	R. P. Blake....	5.00
"	5	C. J. McMasters	5.00
"	5	H. M. C. Skinner	5.00
"	5	T. B. Purves, Jr.	5.00
"	5	W. S. Murrian.	5.00
"	5	H. D. Gordon..	5.00
"	5	H. T. Herr.....	5.00
"	5	Wm. White ...	5.00
"	5	D. J. Redding..	5.00
"	5	Geo. F. Wilson.	5.00
"	5	H. B. Howe....	5.00
"	5	W. M. Paul....	5.00
"	5	W. H. Prendergast	5.00
"	5	Frank Tuma ...	5.00
"	6	A. B. Minton...	5.00
"	6	John G. Platt..	5.00
"	10	B. D. Lockwood	5.00
"	10	G. A. Hancock.	5.00
"	10	G. W. Seidell..	5.00
"	10	Wm. Moir	5.00
"	10	Geo. W. Stevens	5.00
"	10	Thos. Roope...	5.00
"	10	Frank Slater ...	5.00
"	10	J. C. Nolan.....	5.00
"	10	A. T. Berry....	5.00
		Carried forward	$3,170.00

		Brought forward	$3,170.00
Mar.	10	Thos. Rumney..	5.00
"	10	T. M. Gibb	5.00
"	10	R. M. Galbraith	10.00
"	10	M. K. Barnum..	5.00
"	10	C. H. Terrell...	5.00
"	13	Robt. Patterson.	5.00
"	13	I. W. Mahl....	5.00
"	13	I. W. Clark	5.00
"	13	John Player ...	5.00
"	13	Jas. Kennedy ..	10.00
"	13	M. C. Dinkel...	5.00
"	15	Thos. Jennings.	5.00
"	15	C. B. Young ...	5.00
"	15	J. H. Tinker...	5.00
"	15	W. F. Bradley..	5.00
"	22	F. M. McNulty.	5.00
"	22	F. J. Zerbee....	5.00
"	22	J. J. Dewey....	5.00
"	22	Jos. Roberts ...	5.00
"	22	F. J. Harrison..	5.00
"	22	M. R. Davis....	5.00
"	22	Jas. Ashworth..	5.00
"	22	W. F. Dixon...	10.00
"	23	E. V. Sedgwick.	5.00
"	26	R. V. Wright..	5.00
"	26	Geo. D. Brooke	5.00
"	26	Wilber Green ..	5.00
"	30	W. L. Tracy...	5.00
"	30	L. R. Johnson..	5.00
"	30	W. H. Russell..	5.00
Apr.	5	G. W. Butcher.	5.00
"	5	N. W. Norsworthy	5.00
"	10	J. M. Robb.....	5.00
"	11	A. G. Leonard..	5.00
"	13	Geo. E. Branch.	5.00
"	13	C. B. Smith....	5.00
"	21	J. H. Pengelly..	10.00
"	21	Chas. D. Hilferty	5.00
"	21	Chas. A. Bingaman	5.00
"	21	T. McHattie ...	5.00
		Carried forward	$3,390.00

Brought forward			$3,390.00
Apr.	28	P. C. Rusch....	5.00
"	28	T. F. Brady....	5.00
"	28	Wm. Cockfield.	5.00
"	28	Chas. Graham, Jr.	10.00
"	28	J. I. Krauss....	5.00
May	5	Chas. Lindstrom	10.00
"	5	John L. Smith.	5.00
"	5	H. M. Minto...	5.00
"	5	Jas. McDonough	5.00
"	7	Jas. M. Dow...	5.00
"	7	Wm. Kelly	5.00
"	11	A. McCormick..	5.00
"	11	G. A. Gallagher	10.00
"	11	Sam'l Shepard..	5.00
"	11	J. Cardell	5.00
"	11	S. L. Bean.....	5.00
"	19	D. J. Durrell...	5.00
"	19	H. H. Hale....	5.00
"	19	David E. Davis.	5.00
"	19	F. Monlaverdo..	5.00
"	19	David Holtz ...	5.00
"	19	H. M. Curry...	5.00
"	19	D. G. Desmond.	5.00
"	19	Grant Hall.....	5.00
"	19	O. C. Cromwell.	5.00
"	19	John Neville ...	5.00
Carried forward			$3,535.00

Brought forward			$3,535.00
May	19	R. E. French...	5.00
"	19	Robt. A. Johnson	5.00
"	19	W. T. Foster...	5.00
"	19	D. F. Van Ripper	5.00
"	19	Wm. Montgomery	5.00
"	23	W. C. Hayes...	5.00
"	23	H. C. Manchester	5.00
"	23	John Hawthorne	5.00
"	28	J. Piccioli	5.00
"	28	J. Marchbanks..	5.00
"	31	S. Phipps	5.00
June	4	Geo. N. Riley..	5.00
"	4	C. T. McElvaney	5.00
"	4	A. Buchanan ..	10.00
"	4	Geo. Gurry	5.00
"	4	J. G. Clifford..	5.00
"	4	C. J. Bushmeyer	5.00
"	4	F. L. Carson...	10.00
"	4	Geo. O. Hammond	5.00
"	4	M. B. Parker..	5.00
"	4	J. W. Oplinger.	5.00
"	4	I. M. Malone...	10.00
"	4	W. H. Owens..	15.00
Total			$3,675.00

TREASURER'S REPORT.

To the President and Executive Committee:

Balance on hand June, 1905	$1,535.29
June 11, 1906—	
Interest on deposit to May 26, 1906	34.89
Coupons on mortgage bond, Jerome Wheelock	40.00
Total	$1,610.18
Less exchange on check	.10
Total	$1,610.08
Received from Secretary, June 18, 1906	260.71
Total	$1,870.79

ANGUS SINCLAIR, *Treasurer.*

THE PRESIDENT: A motion to refer these two reports to the Auditing Committee will be in order.

MR. J. F. WALSH (C. & O. Ry.): I move, Mr. President, that the reports be referred to the Auditing Committee. (Carried.)

THE PRESIDENT: The Auditing Committee will be announced later. The next in order is the Assessment and Announcement of Annual Dues.

THE SECRETARY: Mr. President, at the meeting of the Executive Committee last evening, the committee recommended that the dues remain as heretofore, $5 per vote.

MR. A. M. WAITT: Mr. President, I move the adoption of the committee's recommendation. (Carried.)

THE PRESIDENT: Now it will be in order to elect an Auditing Committee of three members. Suggestions are in order.

The following candidates were nominated from the floor: A. M. Waitt, A. E. Mitchell, J. H. Setchel.

MR. PETER H. PECK (C. & W. I. Ry.): Mr. President, I move that the Secretary cast a ballot for the three members just named. (Carried.)

The Secretary cast the ballot accordingly and the candidates named were declared duly elected.

THE SECRETARY: I would like to say to the gentlemen of the committee that the books will be ready for them whenever they desire to make the inspection.

THE PRESIDENT: Next in order is Unfinished Business.

THE SECRETARY: There is none on my desk, Mr. President.

THE PRESIDENT: New Business.

THE SECRETARY: Mr. President, under the head of new business I have a communication which was referred to the convention by the Executive Committee at its meeting last evening:

BALTIMORE, January 8, 1906.

Mr. J. W. Taylor, Secretary American Railway M. M. Association, Chicago, Ill.:

DEAR SIR,— Enclosed find my check for $5 in settlement of my dues to June, 1906.

I would appreciate it very much indeed if you will make the motion at the coming annual meeting to have my name placed upon the Honorary

Roll. I am no longer engaged in my calling, and that, together with my advancing years, leads me to feel my usefulness as an active member has passed. I respectfully request this, as it is still my desire to remain identified with a body in whose affairs I have taken the deepest interest and whose annual meetings I enjoyed so keenly, greeting old friends, meeting new ones. Yours very sincerely,

ANDREW J. CROMWELL.

Mr. Cromwell has been a member since 1885. At the meeting of the Executive Committee last evening I was instructed to present this communication to the convention, with the recommendation of the committee that Mr. Cromwell be made an honorary member of this Association.

MR. J. H. SETCHEL: Mr. President, I move that Mr. A. J. Cromwell be made an honorary member of this Association. (Carried.)

THE SECRETARY: I also have a communication from Mr. F. M. Twombly:

60 STATE STREET,
BOSTON, MASS., March 31, 1906.

Mr. Henry Bartlett, Superintendent M. P., Boston & Maine R. R., Boston, Mass.:

DEAR SIR,— Referring to our recent conversation: Having been a member of the American Railway Master Mechanics' Association in good standing for about twenty-three years, and having ceased to be actively engaged in railway service, I would esteem it a great favor if you would place my name before the Executive Committee of the Association with a view to my obtaining honorary membership, as provided in Section 5, Article III of the Constitution.

Thanking you in advance, I am, Yours very truly,

F. M. TWOMBLY.

At the meeting of the Executive Committee last evening I was instructed to present this letter to the convention with the recommendation of the Executive Committee that Mr. Twombly be made an honorary member of this Association.

MR. PETER H. PECK (C. & W. I.): Mr. President, I move that the action of the committee be approved and that Mr. Twombly be made an honorary member. (Carried.)

THE SECRETARY: Mr. President, I have the following communication:

PHILADELPHIA, March 19, 1906.

Mr. Joseph W. Taylor, Secretary, American Railway Master Mechanics' Association, No. 390 Old Colony Building, Chicago, Ill.:

DEAR SIR,— It has been brought to my attention that the American Railway Master Mechanics' Association appointed representatives from its membership to coöperate with the Pennsylvania Railroad System in carrying on the series of locomotive tests at the Louisiana Purchase Exposition, St. Louis, Mo., 1904, the results of which have just been published.

On behalf of the Pennsylvania Railroad system, I wish to thank the American Railway Master Mechanics' Association for its action, and to acknowledge the valuable assistance rendered by its representatives — Mr. F. H. Clark, Mr. C. H. Quereau, Mr. H. H. Vaughan and Mr. F. M. Whyte — as members of the Advisory Committee, during the progress of the tests, and in the preparation of the results for publication.

Yours truly,

A. J. CASSATT, President.

I also have the following communication, Mr. President:

PHILADELPHIA, June 16, 1906.

Mr. J. W. Taylor, Secretary, American Railway Master Mechanics' Association, Chalfonte Hotel, Atlantic City, N. J.:

DEAR SIR,— Will you kindly announce at the Master Mechanics' convention on Monday that Mr. J. W. Study will be at the registering office on the Steel Pier on Tuesday and Wednesday, between the hours of 11:30 and 1:30, and 5 and 6 P.M., to issue passes over the Pennsylvania Railroad and the West Jersey & Seashore Railroad to railroad members of the Association and the immediate members of their families.

Very truly yours,

H. M. CARSON,
Assistant to General Manager.

Mr. Study will be at the other end of the Steel Pier, where most of you have registered.

At the meeting of the Executive Committee last evening it was thought that some changes were necessary in the Constitution, and the Executive Committee proposes certain modifications, which, under the Constitution, should lie over until the next annual meeting, as follows:

A modification of the present Constitution regarding the election of officers was proposed, in order that it might be brought more in accord with the present practice of the Master Car Builders' Association.

To this end it is proposed that Article VIII, Section 1, of the Constitution be changed to read as follows:

ARTICLE VIII, Section 1. The officers, excepting as otherwise herein provided, shall be elected at the regular meeting of the Association held in June of each year. A majority of all votes cast shall be necessary to an election, and elections shall not be postponed.

The President, Vice-Presidents and Treasurer shall hold office for one year, and executive members for two years, or until their successors are chosen, provided, however, that three executive members shall be elected for one year at the time of the adoption of this amendment. Three executive members shall be elected each year thereafter.

Section 2 of Article VIII to be eliminated.

Section 3 should remain as at present.

Article IX, Section 1, a new paragraph.

At the first session of the annual meeting the President shall appoint a Nominating Committee of five members, who are not officers or associate members of the Association, and this committee shall present the names of nominees for officers of the Association for the ensuing year to the Secretary before the election of officers is in order, and they shall be announced by him as soon as received. The election shall not be held until the day after such announcement, except by unanimous consent. Any other three members may nominate candidates for office.

The present Sections 1, 2, 3, 4 and 5 of Article IX should be advanced one number.

A change was also proposed in the provision of the Constitution regarding the requirements for membership:

ARTICLE III.— Membership.— Section 1. The following persons may become active members of the Association on being recommended by two members in good standing, signing an application for membership and agreement to conform to the requirements of the Constitution and By-Laws, or authorizing the Secretary to sign the constitution for them.

1. Those having the rank of master mechanic, mechanical engineer, electrical engineer, superintendent of shops (when they are independent of the master mechanics), having charge of the design, construction or repair of railway rolling stock.

2. Two representatives from each locomotive and car building works.

3. One representative member may be appointed by any railroad company to represent its interests in the Association. Such appointment shall be in writing and shall emanate from the President, General Manager or General Superintendent, or other general officer in charge of the motive power department. Such member shall have all the privileges of an active member, including one vote on all questions, and, in addition thereto,

shall, on all measures pertaining to the determination of what tests shall be conducted by the association, the expenditure of money for conducting same, *or the adoption of standards,* have one additional vote for each full 100 engines which are in actual operation or are in process of purchase by the road or system which he represents. Such membership shall continue until notice is given the Association of his withdrawal or the appointment of his successor.

The second section of Article III to be omitted.

It is also suggested that Section 5, Article III, regarding Honorary Membership, be changed to read "twenty years" instead of "five years."

The Executive Committee also suggests that a committee be appointed to look into the modification of the Constitution regarding the membership of the locomotive companies in the Association.

This is simply a notice at this time. Any action that is necessary should be taken a year hence.

THE PRESIDENT: I will appoint the following committees:

On Correspondence and Resolutions: Messrs. G. M. Basford, A. E. Mitchell and J. H. Manning.

On Obituaries: John Taylor—A. E. Manchester; A. Sauter—J. A. Pilcher; L. M. Butler—F. T. Hyndman; J. W. Philbrick—P. M. Hammett; F. N. Risteen—A. Lovell; J. M. Davies—J. W. Taylor; R. W. Bushnell—T. S. Lloyd; W. P. Appleyard—A. E. Benson; A. J. Pitkin—J. E. Sague; G. W. Cushing—Jacob Johann.

Have any of the members any new business to bring before the convention? If not, we will proceed with the regular order, which will be the reading of reports.

THE SECRETARY: We have a report of progress that is not down on the program. The committee appointed to supervise the Locomotive Dictionary that the *Railroad Gazette* was authorized by the Association in 1905 to compile, reports progress. The work has been vigorously pushed during the last year. A force of draftsmen have been busy in the preparation of drawings for engravings, and the definitions are nearly completed and ready for revision. It is hoped that the volume, in companion form to the Car Builders' Dictionary, will be ready in August.

THE PRESIDENT: The next in order is the reading of the report on "Shrinkage Allowance for Tires, and Design of Wheel Centers." In the absence of all the members of the committee, the Secretary will read it.

REPORT OF COMMITTEE ON TIRE SHRINKAGE AND DESIGN OF WHEEL CENTERS.

To the Members:

At the last year's meeting this committee made a report recommending an increased shrinkage allowance for tires of large diameters in connection with cast-steel centers.

The committee recommended that the present shrinkage of 1-80 inch per foot in diameter be retained for all centers of cast-iron and cast-steel less than 66 inches in diameter; that 1-60 inch per foot in diameter be used for cast-steel and cast-iron centers 66 inches and over in diameter.

In the discussion which followed the reading of the report the argument was advanced that the design, weight and stiffness of cast-steel wheel centers had a great deal to do with the question of loose tires, and a motion was made and carried that the committee be retained to consider the design of wheel centers in connection with the shrinkage of tires, and to make a report at this year's meeting with recommendation for the section of spokes and rims, as well as the method of securing tires with retaining rings to large wheel centers. The following report is submitted:

GENERAL.— The dimensions, design and weight of wheel centers should, in a general way, be of suitable proportions to the weight and power of the locomotive. These recommendations, therefore, will be found somewhat too heavy for locomotives of moderate weight, and will be understood as applying to large, heavy, modern engines of proportions such as are used at the present time.

SPOKES.— In order to properly support the rim and to resist the tire shrinkage, the spokes should be placed from 12 to 13 inches apart from center to center, measured on the outer circumference of the wheel center. Your committee would recommend the following approximate rule:

Number of spokes to equal the diameter of center divided by 4. If the remainder is one-half or over, use one additional spoke. The exact spacing of the spokes according to this rule would be $3.1416 \times 4 = 12.56$.

Wheel centers arranged in this manner would have the following number of spokes:

Size of Center.	No. of Spokes.
38	10
44	11
50	13
56	14
62	16
66	17
72	18
74	19
76	19
78	19
80	20

Among patternmakers and foundrymen there is an impression that an uneven number of spokes should be used, so as to avoid getting two spokes directly opposite each other in a straight line. The following table has been made up on this basis:

Diam.	Circumference.	Recommended Spokes.	Recommended Pitch.
44	138.23	11	12.5
48	150.8	11	13.6
50	157.	13	12.6
54	169.65	13	13.
56	176.	13	13.5
60	188.5	15	12.6
62	194.8	15	13.
66	207.3	15	13.8
68	213.6	17	12.5
70	220.	17	12.9
72	226.2	17	13.3
74	232.5	17	13.6
76	238.76	19	12.6
78	245.	19	12.9

In the above table, the pitch of spokes, measured on the outside of rim, is 12.5 to 13.8.

Spokes at crank hub should not be located at center line of wheel, but on either side, so as not to bring a short spoke directly in line with crank pin hub. Sections of spoke to be from 9 to 10 square inches in area, with form as shown in Fig. 1, for the big end. Section at small end to have an area of from 5¾ to 6 square inches, with form as shown in Fig. 2. These sections are taken at the base of the fillets uniting the spoke to the hub and rims, as shown in Fig. 3 at AA and BB. The metal in these sec-

tions is distributed so as to give the maximum amount of resistance to the shrinkage of the tires, and with this end in view the section is much heavier directly underneath the part of the tread which bears directly upon the rail head.

RIMS.— Cast-steel driving wheel centers should be preferably cast with the rims uncut and shrinkage slots omitted whenever steel foundries will guarantee satisfactory castings. The P. R. R. Co. have been obtaining

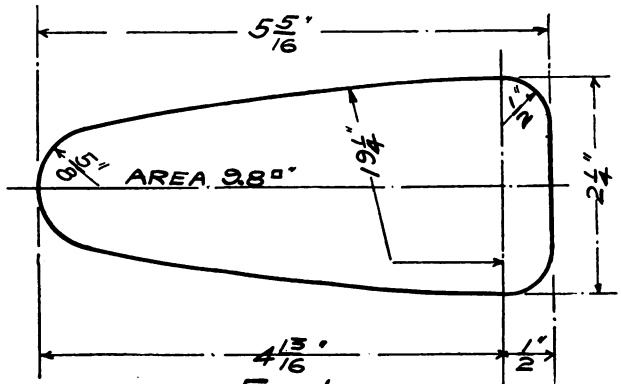


FIG. 1.

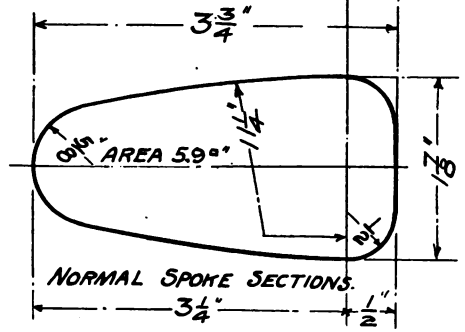


FIG. 2.

wheel centers with uncut rims for the last two years or more. A number of cast-steel foundries are now ready to make wheel centers in this manner.

For wheel centers 60 inches and over, where the permissible total weight of the engine will permit, the rims should preferably be cast solid without cores, so as to obtain the maximum section and have full bearing of tires. The section in square inches should be approximately .45 of the

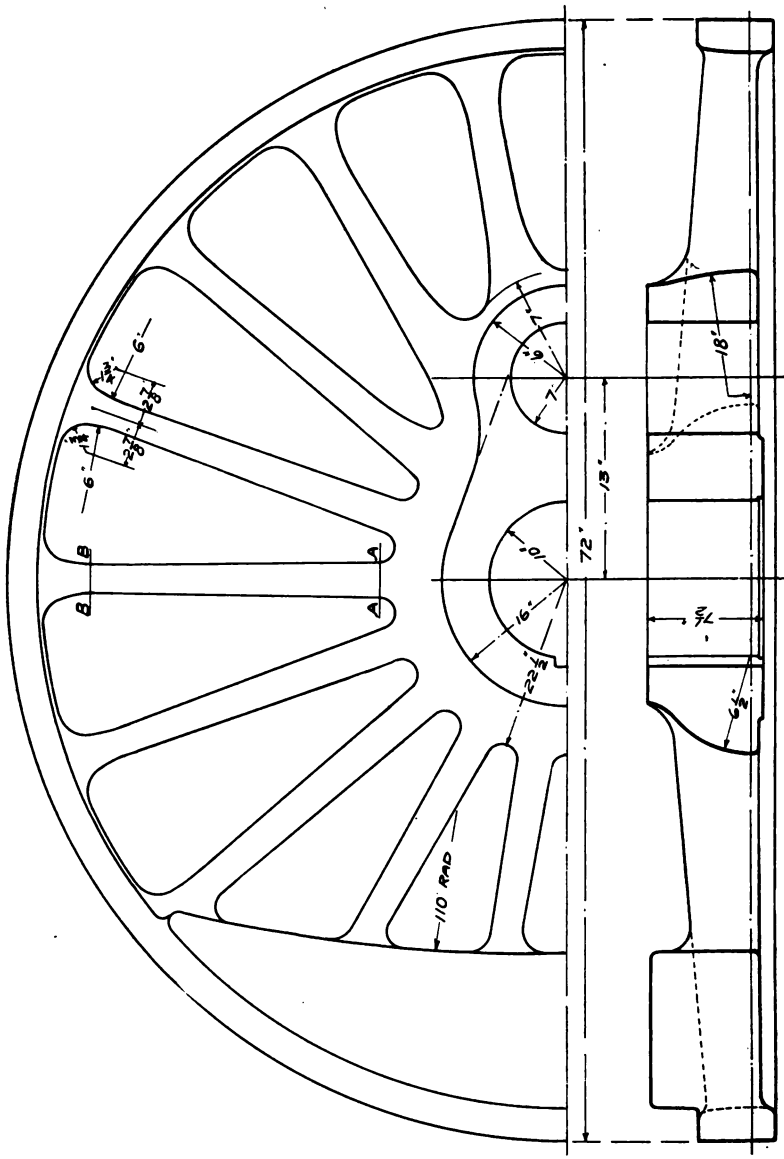


FIG. 3
18 SPOKES

sectional area of the tires when new; for instance, a 5½ by 3½ inch flanged tire has a sectional area of 20.2 square inches. This would require a rim with 9 square inches of metal. A 3 by 5½ inch flanged tire has a sectional area of 17.5 square inches, requiring a rim of approximately 7.9 square inches. In our opinion, it is not necessary to consider the increased area of flat tires.

It is difficult to get sufficient counterbalance in centers smaller than 60 inches in diameter, so that it will be found very desirable to core out

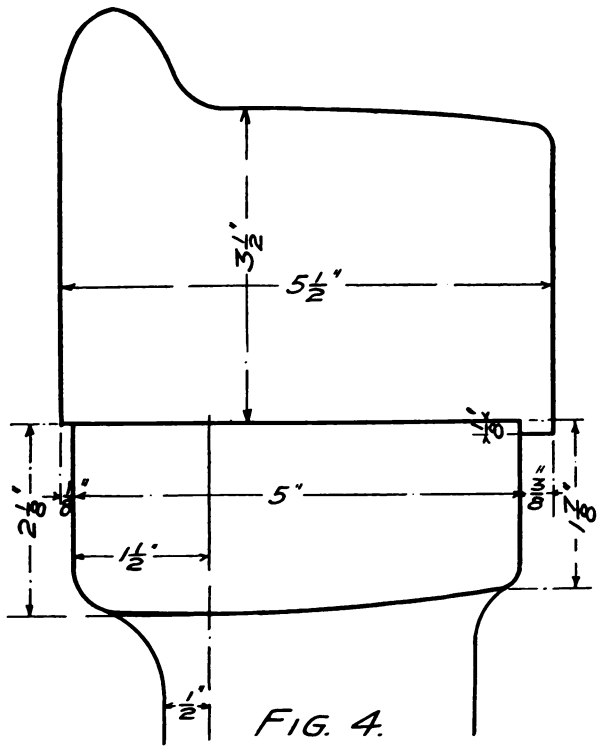


FIG. 4.

the rims to obtain the maximum lightness on the side next to the crank pin, and in some cases on the counterbalance side, in order to fill in with lead where necessary. Your committee would recommend a rim section as shown in Fig. 4, for wheel centers without retaining rings. The tire is secured from having the center forced through it by a lip on the outside ⅜ inch wide and about ⅛ inch high, the tire being left rough at this point. The exact height of the lip therefore depends upon the amount of finish left on the interior of the tire.

RETAINING RINGS.— There is so much diversity of practice in the use of retaining rings that your committee does not feel justified in recommending any particular form.

The standard form used by the New York Central Lines, rim 4 inches wide, is shown in Fig. 5.

The standard form of Pennsylvania retaining segments is shown in Fig. 6. The tire is secured by means of retaining segments and a lip on

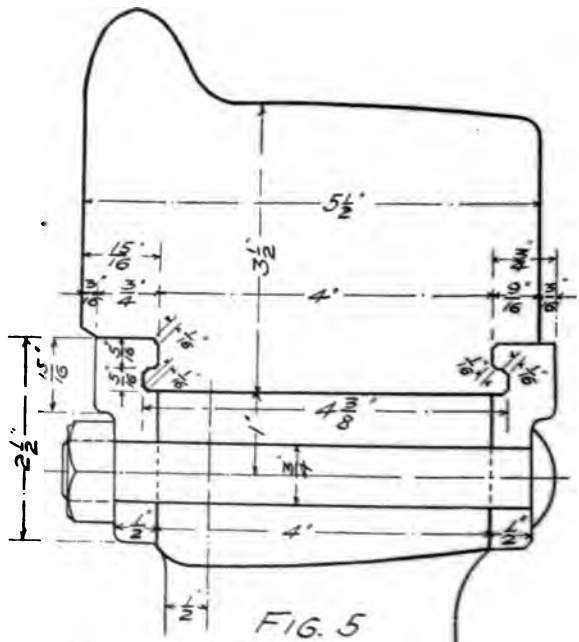


FIG. 5

N.Y.C.&H.R.R.R. RETAINING RINGS.

the outside of the tire. The lip is ⅜ inch wide and about ⅛ inch high, and is equal in depth to the amount left by boring out the tires. The four retaining segments are ⅜ inch thick and about 13 inches long, secured by two rivets through each segment, located at junction of spoke to rim.

The standard form of B. & O. Mansell retaining rings is shown in Fig. 7, with a rim 5½ inches wide.

SHRINKAGE SLOTS. It is becoming more and more the practice of steel foundries to cast rims without shrinkage slots and several of them are now prepared to guarantee satisfactory results. We would recommend the adoption of this practice whenever foundry methods will permit, as the rim of the wheel is stronger and better adapted to resist the strains

to which it is subjected when the rim is left uncut. The extent to which this practice may be used depends entirely upon the attitude of steel manufacturers. It is well known that the shrinkage strains can be taken care of and that cast-steel wheel centers of all diameters required for locomotives have been made successfully in this manner for several years.

HUBS.—In order to prevent an excessive dish to the spokes we would recommend that a standard distance of 55 inches between hubs be adopted.

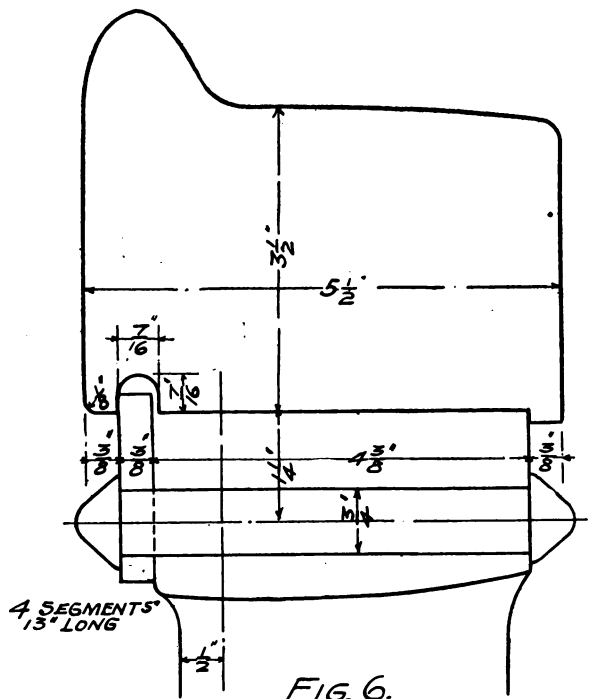


FIG. 6.
P. R. R. RETAINING SEGMENTS.

This permits of the use of a practically straight spoke without dish on the inside.

In boring out the tires and in turning off wheel centers, a wide-nosed tool should be used and care taken that the surface of the finishing cut is not left in ridges. It has been observed that when ridges are left they soon wear flat and decrease the original shrinkage.

Accurate measurements of tires after they have been in service for some time, especially when less than 2½ inches in thickness, show that a rolling out or stretching of the tire occurs, and for reasonably heavy

centers these figures would account more for loose tires than any permanent set in the driving-wheel center.

In Fig. 8 is shown the exact caliper dimensions of the wheel centers and tires which were reported loose on Atlantic engines having about 104,000 pounds weight on drivers. These tires had been previously

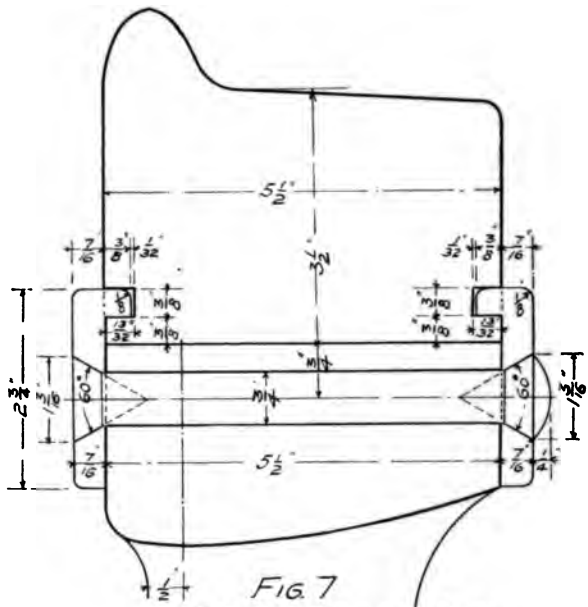


FIG. 7
B & O. RETAINING RINGS

shimmed, and contained liners between the tire and center .068 inch on the left and .050 inch on the right for the entire circumference.

Fig. 9 shows diameter of tires 2⅛ inches thick, which had been removed

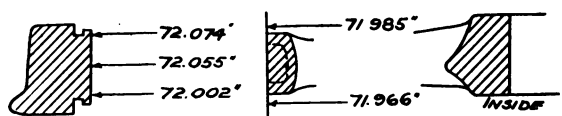


FIG. 8.

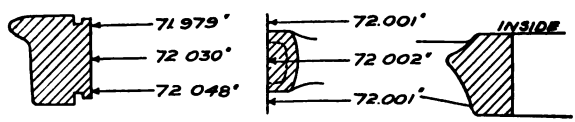
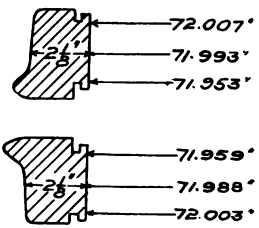


FIG. 9.

from a similar engine. These dimensions appear to confirm the statement that considerable rolling out and stretching occurs when the tire becomes reduced in thickness, and it is especially noticeable that this rolling action



STANDARD BORE 71.925"

FIG 10

of the wheel is most apparent on the outside of the tire where the wear of the rail would be greatest.

F. J. COLE, Chairman,
J. E. MUHLFELD,
A. S. VOGT,
W. A. NETTLETON,
Committee.

NEW YORK CITY, May 21, 1906.

THE PRESIDENT: Gentlemen, you have heard the report of the Committee on Tire Shrinkage and Design of Wheel Centers; what is your pleasure.

MR. C. A. SELEY (C. R. I. & P.): I move that the report be received and opened for discussion. (Motion carried.)

THE PRESIDENT: This is an exceptionally valuable report and it should receive careful consideration and discussion. One phase of the subject which it would be interesting to discuss would be the one as to whether retaining rings are required for large diameter of wheels. Some roads, I understand, are using retaining rings.

MR. G. W. WILDIN (Erie): I do not see exactly how we are going to shim a tire if the recommended design is used. I was in hopes that some members of the committee would be present and explain this particular point. Of course, I refer to the shimming of tires without dropping the wheels.

MR. DAVID BROWN (D. L. & W.): I have had a great deal of experience with the tire shown in Fig. 4, as recommended by the committee. Mr. Wildin's remark is perfectly in order. As far back as 1860 we were using that method on the road I was connected with, and the only trouble we found was when you wanted to shim the tires you had to get underneath to do it. There was more room under engines in those days than at present, consequently it would be a serious matter, at the present time to drop the wheels to shim the tire. It can not be done on the outside, and it is a very difficult matter, with the modern engines, to get to it on the inside. I am not in favor of having a lip on the outside of the tire for those reasons.

MR. GEO. L. FOWLER: I was very much interested in this report, and it is to be regretted that the members of the committee are not here, because there are a few questions I would like to ask in regard to it; especially the last statement, as to rolling-out of the tire. I would like to know whether there has been found to be any difference in the different makes of tires in that rolling-out action. There is a wide difference in the amount of carbon and naturally in the hardness of the tire, in the tensile strength and natural elongation between the different makes. They run from about 55 carbon to 72 carbon. I am speaking of car-wheel tires, and take it for granted that the same variation exists between the tires of locomotive wheels. If the tire is of the higher carbon it would naturally have less elongation and less liability to roll out, and the rolling-out and stretching would undoubtedly be very much less than in the case of the softer tires. The question, therefore, naturally arises, whether it would be better to raise the carbon point in the tires, so that you will have a harder tire and one less liable to this rolling-out action, than you have in the softer tire such as we have been using.

A number of years ago, when the carbon was as low as 40 or 45 in some cases, we had much more difficulty in this respect. The hardness of the tire, as I said before, varies with the amount of carbon in it, and that is a point that it seems to me should be taken into consideration in the design of the tire, and also as to the amount of shrinkage which should be allowed. I also wish

to ask whether the committee made any measurements to find out what the stress on the tire is, after it is shrunk on when used. Of course, there must be some stretching to the tire, and I ask whether that tensile stretching is ordinarily calculated to take up the whole of the shrinkage, and whether measurements have been taken to show what the compression of the center is by which the actual tensile stress on the tire, when finished, is made somewhat less than it otherwise would be. These are points to which I wish to call the attention of the committee, and would be glad to have information about them.

MR. G. E. PARKS (Mich. Central): I believe these dimensions were obtained on the Michigan Central R. R., and I would say to the gentlemen in this connection that two makes of tires were used and both of them showed the rolling action. Although we did not make a chemical analysis, we made a tensile test of one of the tires, and it gave an ultimate strength of something over one hundred thousand pounds.

MR. G. W. WILDIN (Erie): As far as retaining rings are concerned I might say we are abandoning the practice altogether, up to and including 76-inch driving wheels. Since the small projection shown in the design is to take the place of a retaining ring, I would like to see a change made in this respect, having same removed before the recommendations are adopted as standard, as I do not believe it is necessary.

MR. W. G. MENZEL (Wisconsin Central): We do not need a retaining ring when we have tires 3½ inches, but we do when we get them down as low as 2½ inches. The question of retaining rings, I think, should be decided — whether or not it is best to put them on in order to get another quarter-inch or half-inch wear on the tire. We do not need the retaining ring until a tire gets down to 2 inches. Would it pay to put it on to get another quarter-inch? I don't think it would.

MR. G. W. WILDIN: I should like to ask Mr. Menzel if he would run a locomotive with a loose tire because same is equipped with retaining rings.

MR. J. H. MANNING (D. & H. Co.): I am heartily in favor of the retaining ring on our tires, but I do not think it is pos-

sible to have a large tire and continue to keep it tight after it gets down to 2 or 2½ inches. I also think we ought to consider in connection with the retaining rings a means of preventing the tire from turning around. By doing that we would be able then to catch it before it does any damage. It gives a man an opportunity to correct it before it does any serious damage.

MR. F. SLATER (Chicago & North-Western): I am very much impressed with the tire used on the Pennsylvania Line, providing that outside lip were taken off and the inside retaining ring were put on. That would prevent the shifting of the tires in case it should get loose. The division I am connected with is using heavy power and hard service, and we frequently have loose tires. It is a very common practice for us to send men out on the road to get the engine to the nearest side track and shim the tire so we can bring it in. With a projection of that kind it would be quite difficult to shim the tire, and if the tires are fitted up with that inside retaining ring, the tire could not shift, the engine could be brought to its home station and it would save the expense of sending men out on the line — which is not very convenient, but it has to be done.

MR. H. H. VAUGHAN (Canadian Pacific): We are using the lip shown in the sketch on our tires and shimming them from the inside where necessary, and I do not believe we have any very serious difficulty. It seems to me to be an element of safety. In regard to the design of the steel wheel, I would like to call attention to one thing. If you will look at Fig. 4, and take the center line that is shown one-half inch on the inside of the spoke, you will see that the center of the line of the tire is about another half-inch on the outside coming down to the spokes, and turning back to Fig. 2, where the spokes are shown, you will see that the center of the thrust of the tire, tending to collapse the wheel center, is very near the inside end of the spoke, which the committee has made considerably thicker than the outer end. We have gone a step further than that. We have put the bulk of our metal in the spoke right under the line of the thrust of the tire, making a pear-shaped spoke, and reduced the section of the spoke very considerably on the outside. We started to make practically a T-shaped spoke and we came to the pear-shaped

spoke. The wheelmakers say the wheel is a very easy one to mold, and it appears to me correct because it puts the bulk of the metal right under the thrust of the tire. I think that section is preferable to the one suggested by the committee. I do not believe the rim section suggested by the committee is correct, either. We have a considerable number of engines with cast-steel wheel centers, with a rim very similar to this, although perhaps not quite so heavy, and as the tires were thinner we found considerable trouble from loosening, and also we have had trouble from breakages. I charge that entirely to the bending of the rim, with a thin tire, between the spokes. In the old designs of cast-iron wheel it was common to have a rim 3 to 3½ inches deep. That rim had plenty of strength. It would support a thinner tire, and it had strength to do it. Our rims now are all made with practically the same section as the old cast-iron centers with the deep U-shaped rim. While it takes no more metal than the proposed rim it gives a very large additional amount of strength to support a thinner tire. I believe that is better than the section shown here. I would consider the arguments against retaining rings as good, but I would regard retaining rings of value as merely a means to bring the engines in that develop loose tire. The lip should do practically the same thing. I do not see how the tire can work in with the lip on there, and it can not work out under any conditions. We have been making experiments to determine the amount the wheel center collapses when a tire is shrunk on. For instance, you apply a tire with a shrinkage of .001 of an inch to an inch. We happen to strike a design of tender wheel centers that were over size. We would normally have given them .030 shrinkage. They were .030 over size. We were astonished on measuring the tire, after being shrunk on, to find it had come down to within .002 of its cold diameter. The wheel center had given away entirely. That type of wheel center is one we have considerable difficulty with loose tires on, and I think that accounts for it. While you put on .020, or .030, or .040 shrinkage, if you measure the diameter after it is put on you will find the centers have collapsed. Driving-wheel centers collapse as to .025 to .040. I had hoped to have figures here showing the difference between spokes of this section and pear-shaped spokes.

They have not reached me and I am not able to give them. The tendency was in the pear-shaped spoke, with the metal in the direct line of the thrust of the tire, to hold the wheel out and not give way as much as the tire with the spoke, with the section shown by the committee. Another point I think should be referred to in this matter, and that is, where tires are cut they should be fitted with cast-iron spacers. We struck some engines turned out by a locomotive builder a year ago where they were fitted with soft metal spacers. They took away the entire resistance of the rim to hold out against the shrinkage of the tire.

MR. W. G. MENZEL (Wis. Cent.): I agree with the remarks just made, especially regarding the rim. I believe that the retaining ring is simply of assistance to bring the engine in which develops loose tire. I do not think it would be good practice to run the tire, even if it had retaining rings, after it had gotten loose.

MR. DAVID BROWN (Dela., Lack. & Western): The gentleman to the left referred to Fig. 6 and talked of eliminating the lip on the outside and using the other one, the retaining ring, on the inside. Why not go further and also eliminate the retaining ring and make the retainer solid, as part of the rim of the wheel? The tire can be recessed correspondingly to take the projection, the rim of wheel to be even with inside of tire. The road I am connected with has been using this method for some years, and it gives very good satisfaction, preventing the tire from moving in on the wheel.

MR. F. SLATER (Chicago & North-Western): The objection to the lip on the outside of the wheel is that it is very inconvenient to shim the tire. One gentleman has said it was just as easy to shim the tire from the inside as it was from the outside. I can not agree with him on that. We found no difficulty in shimming the tire without placing a jack under the engine or removing a rod. We merely put a jack under the crank-pin and take enough of the weight off to free the tire from the rail. It does not take much. There is no strain on the pin. It merely compresses the driving wheel slightly so as to raise the wheel off the rail enough to take the weight off the tire; then you can put a tire heater around the tire that passes

around outside of the wheel near the rail, and in a very few minutes your tire is warm enough to put tin all around that wheel center, and that engine can go out. It saves a lot of roundhouse work. We shim a tire that way out on the road and in the house. When we have an engine with a loose tire on the line we have a small portable tire heater and we send two men out and use the air from the locomotive, and in a very short time that engine is ready to go on with her train. The engine is not jacked up at all. A small jack is used under the crank-pin, and for that reason the tire that has the inside retaining ring to prevent the slipping of the tire sideways on the rim and removing the outside lip is the better.

MR. P. MAHER (T. St. L. & W. R. R.): I have had considerable experience with tires with and without retaining rings. I do not consider that the retaining rings are used for the purpose of getting more wear out of the tire, but I believe with the use of the retaining ring that more wear can be had and at the same time a greater factor of safety. I am using a retaining ring which is put on in short sections. By the use of the clamp, tires can be shimmed without any inconvenience. Personally, I consider the use of retaining rings or some such device for fastening tires absolutely necessary as a factor of safety and assurance of better service.

MR. G. L. FOWLER: I would like to say one word in reply to a previous question in which it was stated that these tires showed tensile strength of about 100,000 pounds. I should say the carbon in these tires ran between 55 and 60. If the carbon is increased, as it is in some car-wheel tires, it is not a difficult thing at all to get a tensile strength that runs from 122,000 to 124,000 pounds, and with elongation of from eight per cent to ten per cent, whereas, with 100,000 pounds tensile strength, this will probably range from fourteen to fifteen per cent. So it would seem from that that these tires which have been used and examined in this case, were what would be rather soft tires in comparison with the harder ones.

MR. D. J. DURRELL (Penna. Lines West): No question has been touched upon, as to what causes the loosening of tires, more than the suggestion that the rolling of the tire on the rail elon-

gates the section. The action of the brakes, probably, has the greatest tendency toward loosening tires — especially thin tires. We have recently made some investigations as to the thickness tires should be run upon our Atlantic type engines before the tires should be removed, and have found that two inches should be the limit allowable for the tire on this class of engine, having 80-inch drivers. The question of shimming tires having a retaining ring is not a serious one with us; we have no trouble whatever in making the shims, and in doing it in a very short time. Increased thickness of tire in service is, I think, one that should be largely considered in connection with the question of loose tires. The retaining ring is an element of safety, which I believe we owe to the traveling public as well as to our train employees, and can not well be overlooked. Possibly, upon freight and shifting locomotives, the retaining ring might be dispensed with, but I do not think that in high-speed express passenger service we should eliminate this feature.

THE PRESIDENT: What disposition do you wish to make of this report, gentlemen? There are a number of recommendations; perhaps it would be better to consider the referring of the recommendations to letter ballot.

MR. C. A. SELEY (C. R. I. & P.): I think the matter is of sufficient importance to lay over for one year before referring to letter ballot. We have the matter before us now in the form of a tentative report from the committee, and I would make that as a motion — to lay it over for one year before being submitted to letter ballot.

(Motion seconded, put to vote and carried.)

THE PRESIDENT: Is it your wish that discussion on the subject be closed at this time?

(Motion made, seconded, put to vote and carried.)

THE PRESIDENT: The next report is on the subject of "Flexible Stay Bolts."

THE SECRETARY: I have the following note from Mr. O. H. Reynolds on behalf of Mr. Durborow, the chairman of the committee, who says that Mr. W. H. Newberry, one of the engineers of the Pennsylvania Motive Power Department, and who

made the tests and formulated the data in the report at the instance of Mr. Durborow, is present by courtesy of Mr. Durborow to answer any questions the members may wish to ask.

The paper was presented by Mr. Newberry.

REPORT OF COMMITTEE ON FLEXIBLE STAY BOLTS.

To the Members:

To those who are familiar with the stay bolt question it is not necessary to dwell upon the importance of this feature of boiler design, for the numerous and expensive failures of these connections between the fire box and outer shell are fully realized, and also that the number of failures has increased with the increase in size and pressure-carrying capacity of the boiler, and that, at the best, the conditions surrounding stay bolts are most unfavorable to a long life. Any scheme, therefore, whether it be some simple change in design of the construction of the fire box, by the use of a different stay bolt material, or by some flexible connection between these two sheets that will greatly reduce, or better, entirely do away with these failures, increasing the safety and decreasing the maintenance cost, would undoubtedly be favorably acted upon by those needing relief. This question, in one form or another, has been before this Association since its inception, and even though the development has been slow and chiefly in one direction only, partial success has been obtained, and to show what has been accomplished your committee was appointed to report on Flexible Stay Bolts, number in use, manner of applying and service rendered.

The original flexible stay bolt, as far as can be determined from research by your committee, appeared about 1878, and was the invention of Herr Wehrenfennig, then Chief Engineer of Material and Traction of the North-Eastern Railway of Austria, who also, it is claimed, was the first to draw attention to the need of a flexible connection between the two sheets of the boiler. Descriptions of several forms of flexible bolts were given in the technical press of that day, and two of these forms are shown in Figs. 1 and 2. This bolt in general design is similar to practically all that have followed, having a bolt proper with an enlarged head for applying and provided with a seat bearing against another seat provided for in a sleeve screwing into the outer sheet. The fire box end was either fastened by riveting over or by screwing into a cap, but the main difference between this design and later ones is in the form of the seat which, in the Wehrenfennig, was flat, while all others have employed the ball and socket form.

No record of the service given by these bolts can be found, but about four years later an improved form of this bolt was devised and put in service by Mr. W. Leech, Foreman Boiler Maker of the Rajputana-Malwa

Railway of India, who, in describing his bolt (Fig. 3), stated that a large number were put in service in engines running in bad water districts, and that the bolts gave unqualified success, lessening stay-bolt renewals and prolonging the life of the boiler sheets. This bolt was sometimes fitted with a screw cap instead of the copper disc as shown, but its use was not advocated as the copper disc was cheaper and easier applied. This disc was punched from sheet copper to the proper form and then applied to the sleeve with a small, light, hand press which forced the copper into the recess, thus making a steam joint capable of withstanding the pressure of that day, but would hardly meet present day conditions.

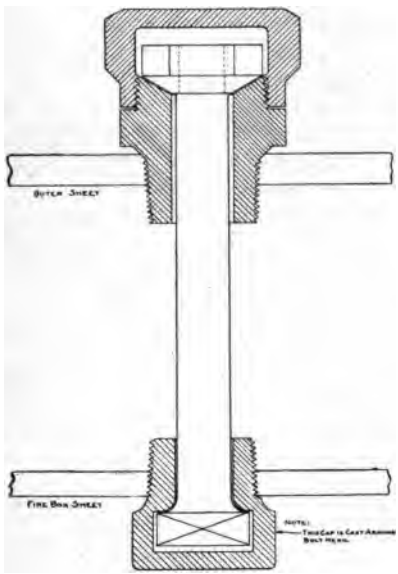


FIG. 1.

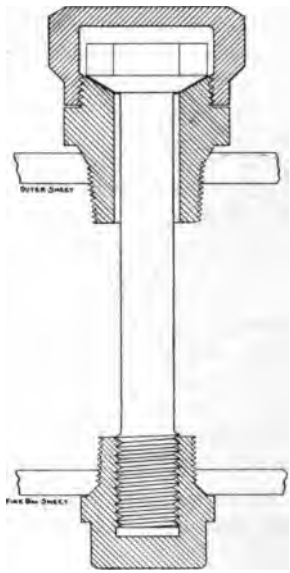


FIG. 2.

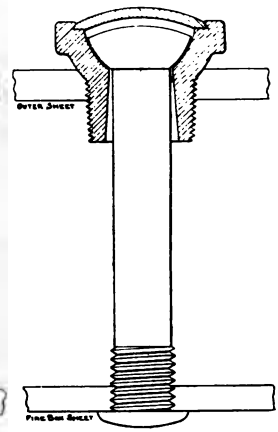


FIG. 3.

Both the Wehrenfennig and Leech bolts were applied by first tapping the inner and outer sheets so that both holes were in alignment, next applying the sleeves and lastly the bolt itself by means of the square head extending from the head of the bolt, against which a sledge or "dolly" was held while the fire box end of the bolt was being riveted over, the head remaining as an integral part of the bolt in the Wehrenfennig design, but is removed from the other form after it has served its usefulness in applying the bolt.

Your committee has no data as to how great an extent these early forms of flexible stay bolts were used, but it is known that Leech never profited by his invention, from which it would appear that this was one of the useful inventions whose merit was not fully recognized during the life

of the patent. This brings the subject to practically the present day, and to determine the experience of members of the Association with bolts of this general form, your committee issued a letter of inquiry — copy of which is submitted (See Appendix I) — to which letter fifty-eight replies were received, which may be considered as a satisfactory result, even though this does not represent a large percentage of the members of the Association as being interested in the subject. Thirty-two of the fifty-eight replies received were from roads not using flexible stay bolts, but in the twenty-six answers from roads using them, a number of the most prominent roads were included.

Five hundred and twenty-one thousand, four hundred and thirty-five (521,435) flexible stay bolts, of seven different varieties, distributed in 3,012

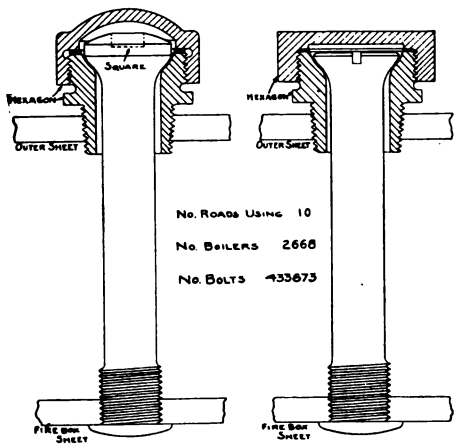


FIG. 5. FIG. 4.

boilers, have been put in service among the twenty-six roads using such bolts. These seven forms are shown in Figs. 4, 5, 6, 7, 8, 9 and 10, and of these forms those shown in Figs. 4 and 5 have been the most largely used. The design shown by Fig. 4, which is the earlier one, developed several serious defects traceable to the screw slot by which the bolts are screwed into the sheet. These failures were usually from the bottom of the screw slot through or into the neck, and in some cases in the neck itself. In the former, the head doubled on itself, closing the screw slot, giving very insufficient bearing on the spherical surface. Stopping the slot short of the edge to prevent this buckling did not prove to be a satisfactory solution; hence this form, shown in Fig. 4, has been largely superseded by that shown in Fig. 5, though the service with it can not be said to have extended over a sufficient period to justify a decision as to its merits. The bolt employs the ball and socket head, but does not use the conical walls for the sleeve

for breaking up scale deposited, and aside from the fault indicated previously, Fig. 4, has given satisfactory service, some roads replying that they have experienced no failures, but all roads that have adopted it as standard report otherwise, showing the advantage of wide experience.

In point of favor, indicated by the number in use, Fig. 6 follows the preceding forms, and, regarding the design, appears to be the most satisfactory, as only one road reports a failure, this failure being caused by faulty manufacture in punching the hole for the wrench too deeply. The ordinary ball and socket joint, having a bearing between the bolt and the sleeve, is used, the walls of the bore of the sleeve being conical and very short, and your committee believes that this latter feature is an improvement

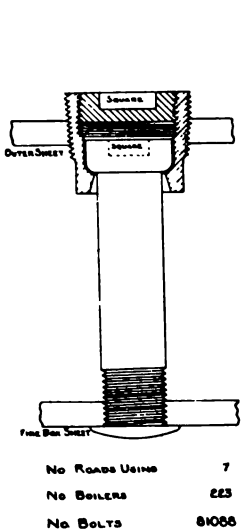


FIG. 6.

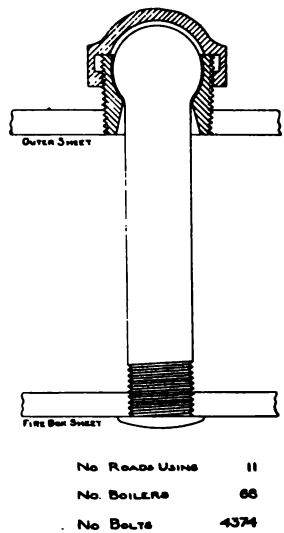


FIG. 7.

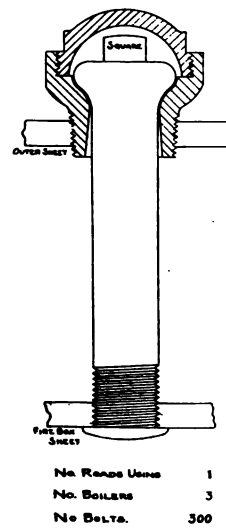


FIG. 8.

on the designs shown by Figs. 4 and 5, inasmuch as the space for the lodgment of scale is lessened.

Fig. 7 shows the latest design, and though of comparatively recent date has been received with great favor, indicating the rapidity with which a new bolt of promising design is given a practical trial in the effort to cure the stay bolt trouble. Its actual service, however, has been of such short duration that nothing can be said in its favor or otherwise. The principles of this design were used in an older form and include the spherical headed bolt and recess with conical walls in the sleeve, but better designed for manufacture and for application.

The form shown in Fig. 8 is a bolt that possesses no special features, and has had a small application and short service.

The preceding flexible bolts represent those reported on which are in service at the present time and may be taken for guidance in future designing. The bolts following are those that have been in service but withdrawn as not approaching requirements. The first of these latter, Fig. 9, patented in 1900, was a radical departure from its predecessors and was composed of a sleeve of mild steel forged to a square head at one end, with a semi-spherical recess formed in the other for the reception of a spherical headed bolt of the same material. The sleeve was heated, the bolt inserted in the recess and the lower edge of the sleeve shaped to conform to the lower half of the bolt head, obtaining a spherical-headed bolt retained in a spherical recess in a sleeve, but with sufficient clearance to allow free movement

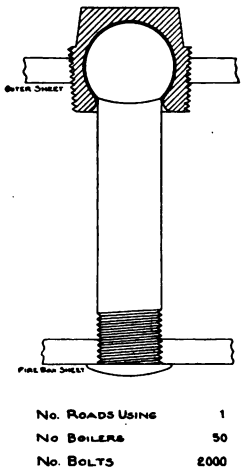


FIG. 9.

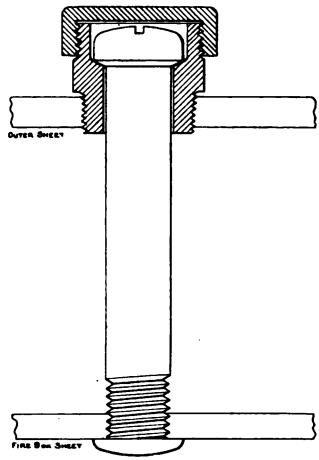


FIG. 10.

within the sleeve. It was necessary to insert the bolt and sleeve together through the outer sheet and screw both simultaneously into their respective sheets, one man on the outside applying the sleeve and a helper in the fire box providing for the bolt, it being of extra length for this purpose. As the bolt was free to revolve in the sleeve the threads in the inner sheet did not have to be a continuation of those in the outer sheet of the boiler. Aside from the method of construction the distinctive feature of design is the spherical head working in a recess of like shape, thus preventing the accumulation of solid matter above the head of the bolt and stopping any motion that should take place, maintaining the bolt in a flexible condition. The road reporting this bolt had a rather extensive equipment, and for a period of two years had no failure, indicating excellent service. Due to the amount of metal removed from the boiler sheet in applying, the difficulty of inspection, and the awkward method necessary for its installation, its use was abandoned.

A further example of a bolt not meeting the demands is shown by Fig. 10, which was discontinued as it would not remain steam tight, and the difficulty encountered with its becoming rigid when scale was deposited, but as its general design differs so little from other bolts, it is hard to see just why it should develop these faults particularly.

It has been demonstrated that in certain locations the rigid stay bolt will not give reliable service in the large boilers carrying heavy steam pressure, and though very frequent examination will detect such failures before they become too numerous, nevertheless there is every indication that at certain locations some form of bolt that will allow of distortion without rupture is a necessity.

For solid bolts, some advocate a special grade of material, this being either a higher grade iron made up in the usual way, or iron made up in

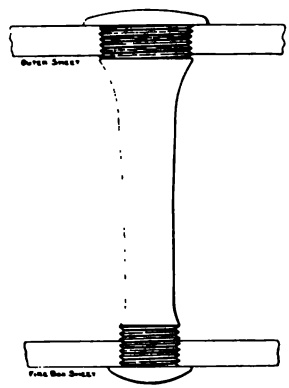


FIG. 11.

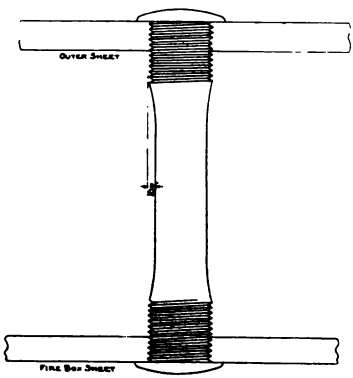


FIG. 12.

some special way. Your committee believes that, while good material is by all means desirable, it is firmly convinced that this alone will not overcome the troubles that have been experienced.

Besides changing the material, various modifications in the form have been tried and adopted, the general idea being to so shape the bolt that the vibration strains will not all locate themselves at one point, namely, the inside of the outer sheet. One of these special forms is shown in Fig. 11, the bolt being materially enlarged at the outer sheet, diminishing in diameter until the fire sheet is reached, the governing idea being that, by so shaping the bolt, the deflection will be distributed over its entire length. Experience shows that this result largely follows and that final fracture, when it occurs, may be at some distance from the sheet, but the disadvantage of tapping holes of different sizes in the two sheets, to say nothing of the greater expense of forming such bolt, renders its adoption very doubtful. The custom of reducing the diameter of the bolt between the two sheets, Fig. 12,

your committee believes to be a good one, provided the reduction is not made by an abrupt shoulder. Vibrating tests on the testing machine indicate that this reduction very greatly increases the capacity of the bolt to resist distortion, but it is the opinion of your committee that the reduction should not be carried too far, as it has been found in practice that with the size of bolts customarily used, a body 3-16 inch less in diameter than that of the ends will give better results than a greater or lesser amount of reduction. Other forms of solid bolts have been used in fittings designed to practically increase the length of the bolt, and an example of this is shown in Fig. 13; the interior of the sleeve being of conical form, the diameter of the tap being such as to give but a short bearing for the bolt at the outer end of the sleeve. With good water, this appears to be a very desirable change, but where the water forms hard scale, the design is not

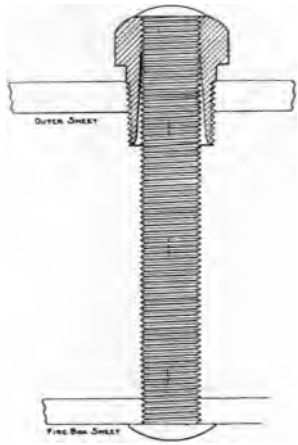


FIG. 13.

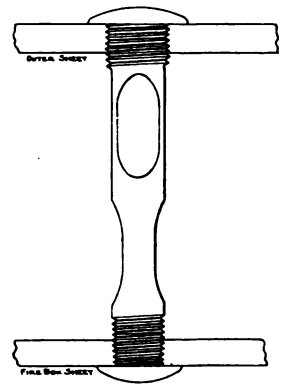


FIG. 14.

successful, as scale forms between the bolt and the interior of the sleeve, so that finally the bolt is rigid and the available length is no greater than that of the ordinary design.

Various modifications have also been made with the idea of giving the rigid bolt greater flexibility. One of these is shown in Fig. 14, where the bolt is flattened locally in planes at right angles to one another, but the results obtained were not satisfactory.

Other modifications, such as the milling of longitudinal saw-cuts in the body of the bolt, and of manufacturing the bolts in hollow form, have also been tried; the latter claiming to possess the additional advantage of better combustion and absolute indication of failure. Your committee is not prepared to admit that either of these claims have been proven.

All these schemes have given more or less satisfaction, but none have fulfilled requirements to an extent that would warrant universal use.

Regarding the opinions of the users of flexible bolts as to the value resulting from a change from the rigid to the flexible form, the verdict is greatly in favor of the change, fifty per cent of the replies received being in the affirmative and including the largest users; the remainder, excepting one, answering in a manner that could not be interpreted as either for or against their value.

The road replying definitely in the negative uses two of the forms which have received the most favor, and the equipment, though somewhat smaller than that of the average, is still large enough to give an idea of the value of the bolts. Unfortunately, this road makes no explanation and does not report any failure of flexible stay bolts, hence it is difficult to assign a reason for this adverse report, unless it be that the experience has been too short to warrant a favorable report, or, possibly, it may be due to a misunderstanding as to the explanation desired.

One other road gave a rather vague reply, but the indication is that flexible bolts on this road have not proven their value. The road in question is a very large user of flexible bolts and has come to the conclusion that with a properly designed boiler and using rigid bolts of best material, all requirements will be met; so with this idea, equipment now being built has been ordered without flexible bolts, but in such equipment that has flexible bolts they will be maintained as standard.

Table I

NUMBER OF ORDINARY AND FLEXIBLE STAYBOLTS BROKEN IN ONE YEAR.

DIAGRAM NUMBER (see Fig. 27-44)	NUMBER OF LOCOMOTIVES	STEAM PRESSURE	NUMBER OF STAYBOLTS PER FIREBOX		TOTAL STAYBOLTS ALL LOCOMOTIVES		TOTAL STAYBOLTS BROKEN		PERCENT OF STAYBOLTS IN SERVICE BROKEN IN A YEAR	
			ORDINARY	FLEXIBLE	ORDINARY	FLEXIBLE	ORDINARY	FLEXIBLE	ORDINARY	FLEXIBLE
	6	205	794	94	4764	564	———	———	———	———
27	18	130	626	34	11268	612	548	5	4.86	.8
28	15	205	823	181	12345	2715	232	182	1.88	6.70
29	23	205	918	235	21114	3405	21	3	.0994	.088
30	20	205	752	186	15040	3820	207	106	1.37	2.70
31	10	205	721	186	7210	1860	854	34	11.8	1.8
32	21	180	747	92	15687	1932	227	34	1.45	1.76
33	49	225	1010	16	49490	784	335	29	.677	3.70
	1	225	707	162	707	162	———	———	———	———
34	50	140	615	82	30750	4100	393	20	1.28	.49
35	43	140	558	138	23994	5934	536	41	2.23	.69
36	71	150	595	85	42245	6035	513	150	1.21	2.48
	80	205	893	113	71440	9040	2388	141	3.34	1.56
37	142	205	890	216	126380	30672	154	4	.122	.013
TOTAL	549	———	10649	1830	432434	71735	6408	749	1.48	1.04

(NOTE.— Figures referred to in Table I are 29 to 45 and not 27 to 44, In first column figures 29, 30, 31, 32, 33, 34, 35, 36, 37, 38 and 39 should be substituted for those given.)

To show the comparison of service of rigid and flexible bolts, Table I, made up from information submitted, is given. From an inspection of the table the life of the flexible bolt, comparing the percentage of failures to the total bolts, does not show to a very great advantage, but the bolts from which the table are made are those of Figs. 4 and 5, one of which is an admittedly weak design, and further, that flexible bolts as a general rule are only applied where rigid bolts have failed, and so are withstanding much harder service. No data were submitted from which a table could be made to show the comparative maintenance cost of rigid and flexible bolts.

Concerning the location of flexible bolts there appear to be four places applicable to all boilers that have proved to be a source of trouble to rigid bolts, and where the application of flexible bolts has stopped entirely, or to a great extent, the failures of the older form, these places being the two upper corners of the throat and side sheets. Beyond this the application is increased as the individual judgment indicates, one road reporting that every alternate bolt is flexible, they having had such good results with the arrangement shown by Fig. 15 that the one shown by Fig. 16 has been adopted as standard. One other road has every bolt flexible (Fig. 17), but only one engine is so equipped and no results of such a practice were submitted. To show the location and general designs of boilers to which flexible stay bolts are applied, Figs. 15 to 27 are given, they being copies of the blue-prints submitted in answer to the circular of inquiry.

Naturally the results obtained from flexible stay bolts vary to an extent, depending upon the conditions, these conditions including such items as design of the bolt, application of the bolt, design of the boiler, and incrustation, these four factors being the most important affecting its life. In the bolt itself it is admitted that, strictly speaking, it is not a flexible bolt, for though it is made in two parts it still has to withstand bending strains, due to the manner of expansion in the sheets, the bending taking place at some point near the inner sheet. This action can be overcome by employing a flat bearing surface at right angles to the head of the bolt instead of the ball and socket joint as commonly used. As better contact is maintained between the head and sleeve in actual service with the ordinary form, and further, as trouble has seldom been known to result from the bending strains due to the expansion of the sheets, which would be indicated by bolts breaking at some point near the inner sheet, or by leaking at the fire-box end (a trouble that is seldom, if ever, encountered), it is evident that this is a trifling fault, but one that should be borne in mind while considering the designing of new bolts. The finding of the point of failure of stay bolts at the outer sheet, and that the failure seldom, if ever, takes place at the inner sheet, is possibly due to the high temperature of the fire box making the inner sheets more elastic. This allows them to bend to an extent, relieving the stay bolt to some

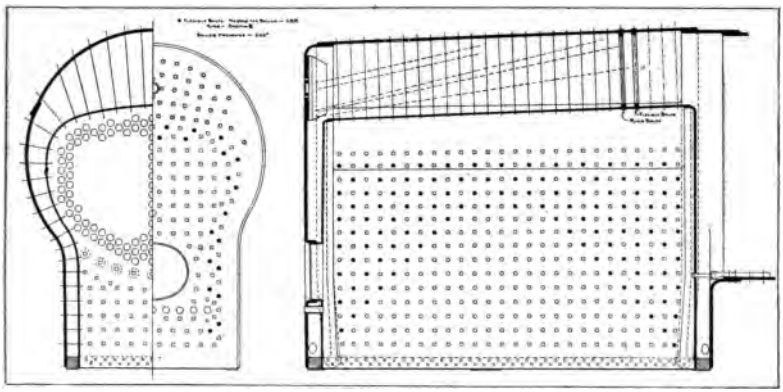


Fig 13

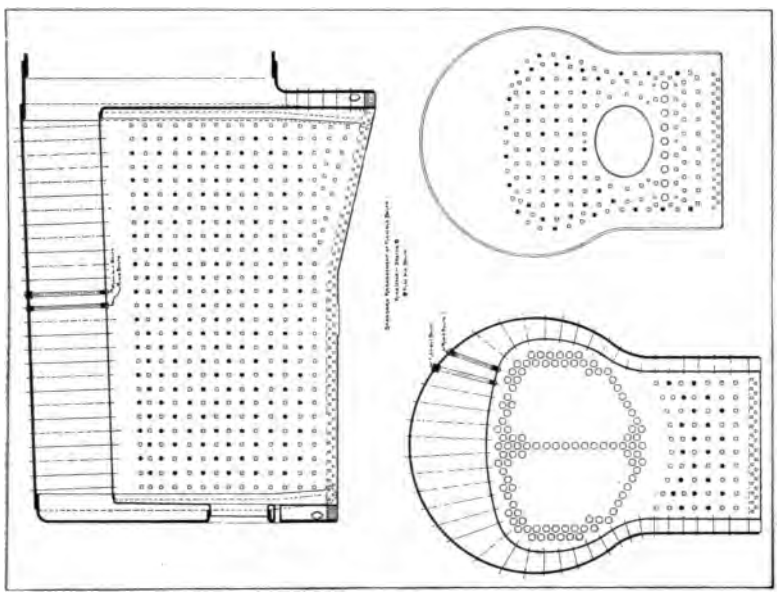


Fig 16

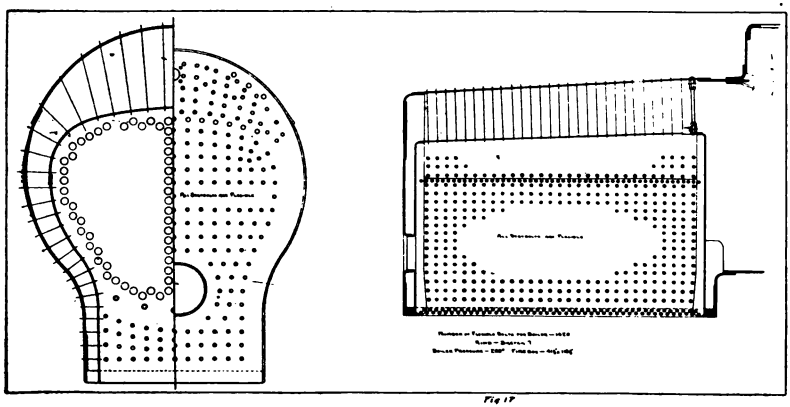


Fig 17

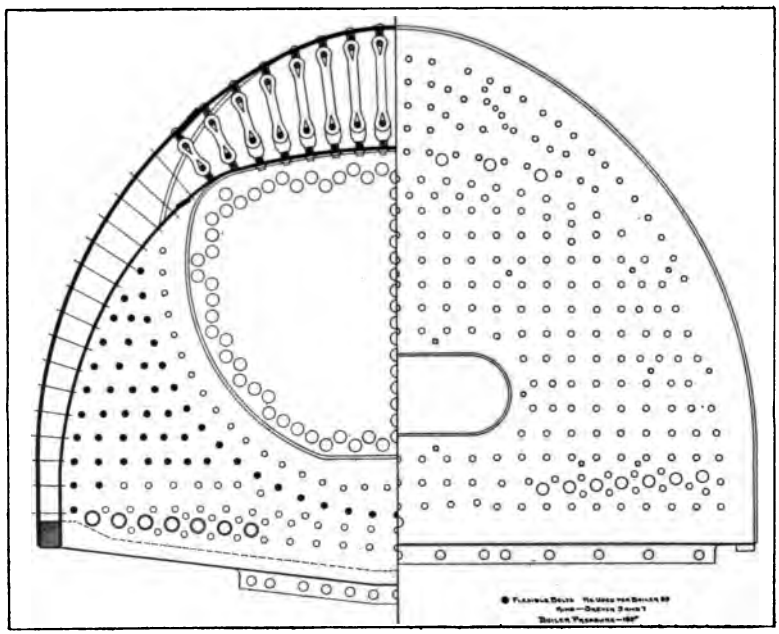


Fig. 10 , 11

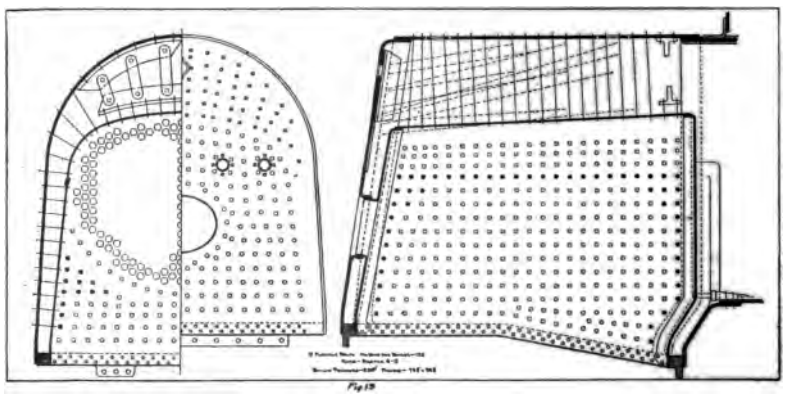


Fig 12

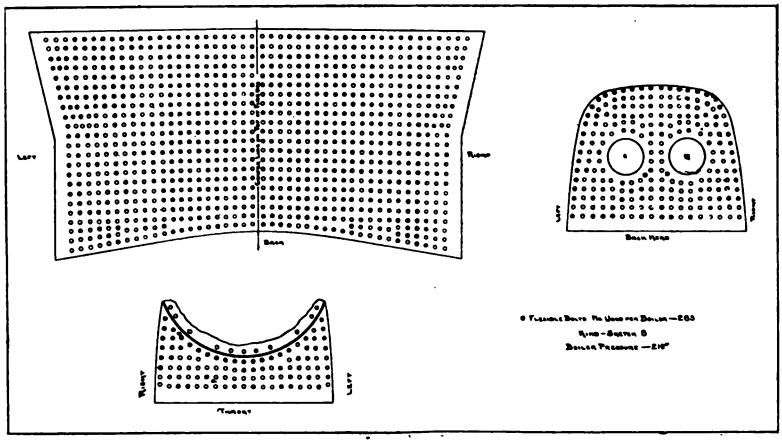


FIG. 20.

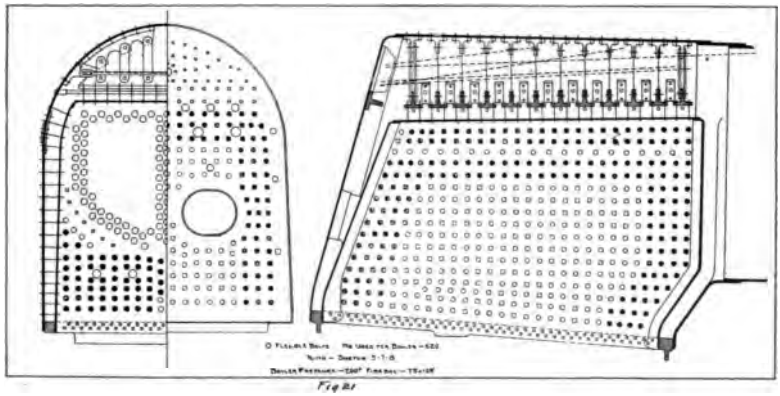


Fig 21

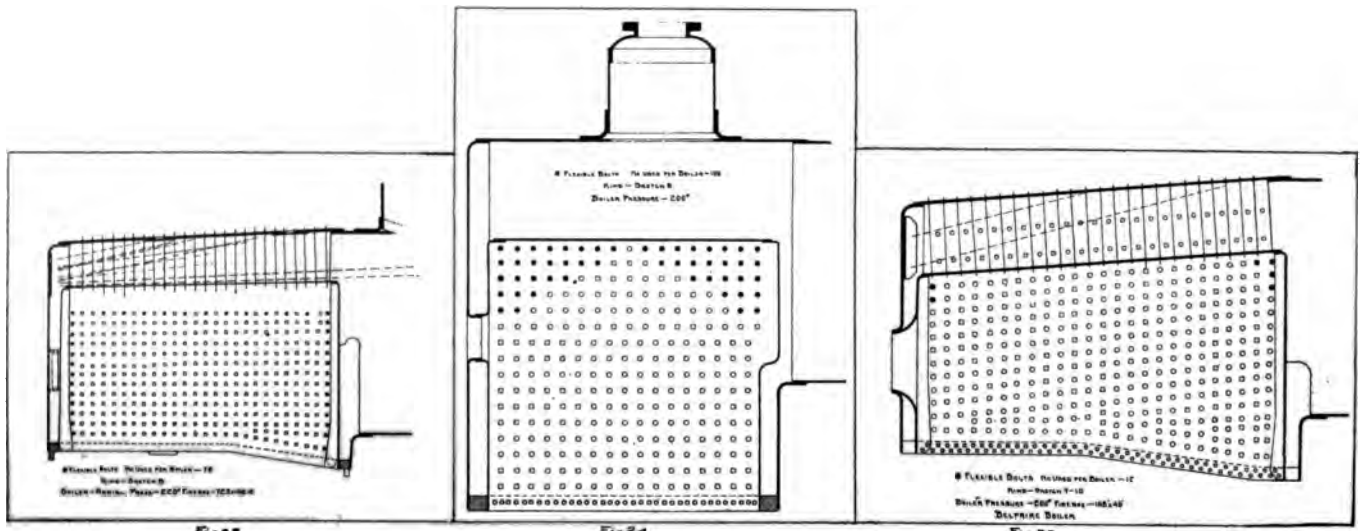


Fig 22 Fig 24 Fig 23

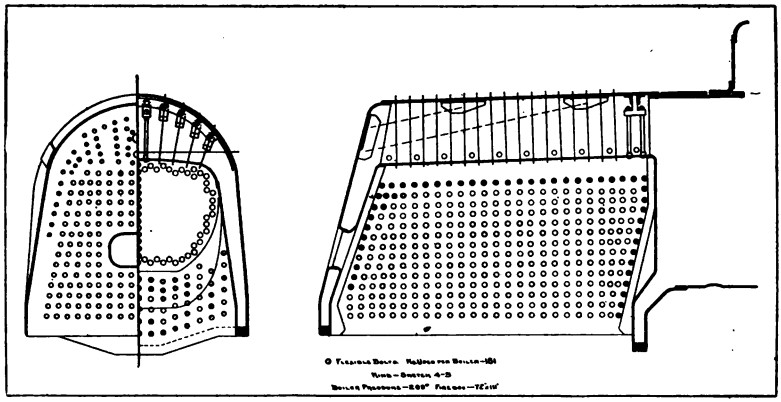


Fig 25

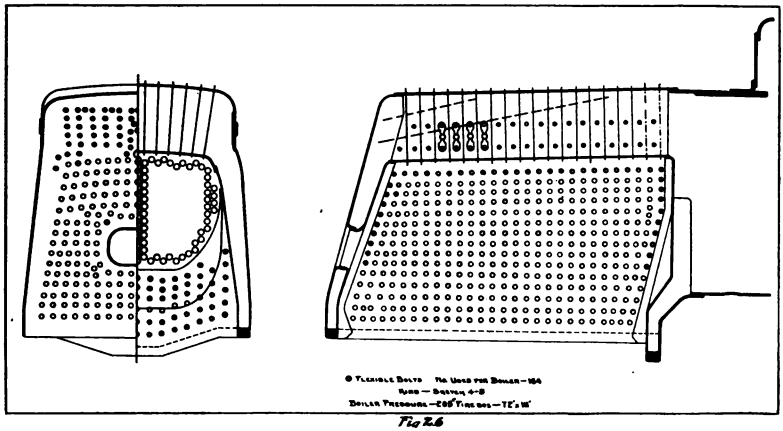


Fig 26

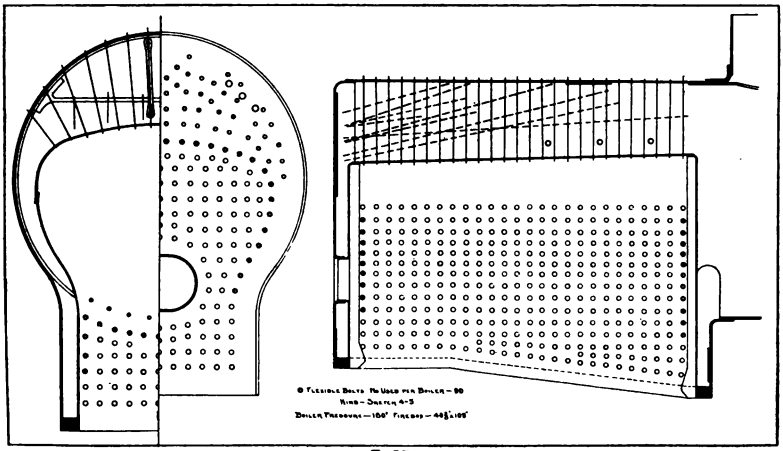


Fig 27

degree of the strains imposed upon it at this point. It should also be remembered that in most designs the outer sheet is materially thicker than the inner or fire box sheet.

A simple means of positively detecting cracked and broken bolts is an improvement needed by all flexible bolts that are in service at the present time. The removal of the cap, which will allow a proper examination of the bolt, is the only absolute means possible with flexible bolts of present design. On account of corrosion, it is not an easy method and often results in destruction of the cap. The inspection of flexible bolts located in side sheets and back head can only be made by the removal of lagging. The designing of the flexible bolt, Fig. 28 for example, so that the telltale hole

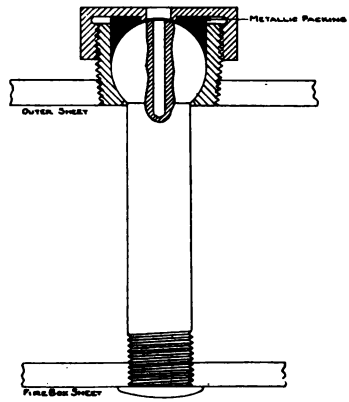


FIG. 28.

may be employed, by filling the space between the head of the bolt and the cap with a packing material, may or may not be a good feature for determining cracked and broken bolts. As the use of the telltale hole is a disputed practice, its action not being accepted as positive, and as it adds to the expense of application and maintenance, it is not to be recommended for this purpose.

The first consideration in the application of bolts should be the securing of proper alignment of the holes in the inner and outer sheets, in order that the clearance between the bolt shank and the sleeve may not be decreased, leaving a larger amount on one side than on the other, and so reducing its value as a flexible bolt when expansion of the sheets takes place, as this will give the possibility of an added strain upon the bolt due to the bolt shank acting as a lever arm with the sleeve as a fulcrum. Also if the bolt and sleeve do not contain the same perpendicular for a center line an indirect strain comes upon both members. These two conditions, which may occur in conjunction, giving complex strains to the bolt and

sleeve, will undoubtedly affect the life of the bolt to some extent; but even if each occurs separately, the already severe service of this member of the boiler is unnecessarily added to, reducing its life to an extent commensurable with the increased demands. The cure for these faults is simple, only needing care in the final reaming and tapping of each pair of holes. Unfortunately, however, none of the methods employed in the application of flexible stay bolts were described by the members in their reply to the circular.

There also exists the possibility that in applying the bolts, different ones may be given varying initial strains, those receiving the greatest naturally suffering the hardest service, and it is easily seen that with a great enough difference in initial strain between one bolt and those surrounding it, rupture may be an easy matter.

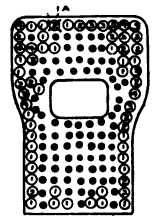
The effect of the design of the boiler upon the life of the bolt can be seen from the accompanying diagrams, Figs. 29 to 45, inclusive, which give the records of broken stay bolts. These figures show the failure of both flexible and rigid bolts, and the tabulations on these sheets show the method of indicating such failure and, also, give other information from which it can be said that each class of boiler has its own local weakness at which failure occurs most frequently; but in general it may be said that the point at which there is a bend in the sheet is one where failure may be expected. In some of the later designs, particularly those of wide fire boxes, the greatest number of failures occur at the first few rows above the mud ring.

Incrustation has been the principal difficulty that flexible bolts have had to contend with and this trouble has been the cause assigned for most failures, there being but little doubt that this is true, for the deposit of solid matter around the bolt and its parts will defeat the purpose of the flexible bolt, making it of little more value than the rigid; and, though the fault may be a local one, affecting only such engines as run in districts supplied with scale-forming water, any design of flexible bolt which will admit of this taking place is in general a weak design.

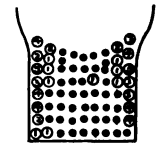
It may be said that all bolts of to-day possess this fault, though some, in a manner, have obviated the difficulty. A fault common to all lies in the sleeve, which should not be made too large on account of weakening the outer sheet, nor should the bolt be decreased for reasons of strength, the result of either being an increase of clearance around the bolt. The proper procedure is the omission of that portion of the sleeve below the seat of the bolt, somewhat after the manner of those shown in Figs. 6 and 9, though carried to a greater extent, thus preventing the possibility of the scale being deposited between the bolt and sleeve, preventing free movement of the bolt with the movement of the sheets. Some designs have made use of a conical wall in the sleeve to aid in keeping the scale from collecting, but it has been found from experience that this feature, aided by the movement of the sheets and continual jarring of the engine, does not serve its purpose under all conditions. Such scale that is deposited is formed grain by grain, and may result in a hard, homogeneous mass which will take a heavy blow

RECORD OF BROKEN STAYBOLTS
1904

No OF ORDINARY BROKEN STAYBOLTS	54
" " ADJUSTABLE " "	3
TOTAL NUMBER OF " "	343
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX	8 16
" " " ADJUSTABLE " "	3 4
" " " LOCOMOTIVES	1 8

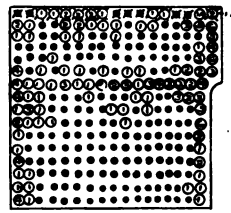


DOOR SHEET

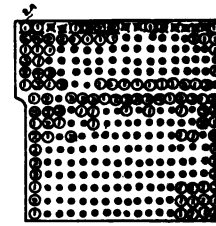


FLUE SHEET

ORDINARY STAYBOLTS NOT BROKEN — •
" " " BROKEN — O
ADJUSTABLE " " NOT BROKEN — ⊠
" " " BROKEN — ⊠
EITHER ORDINARY OR ADJUSTABLE — ⊠



LEFT SIDE SHEET



RIGHT SIDE SHEET

NOTE —
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig 29

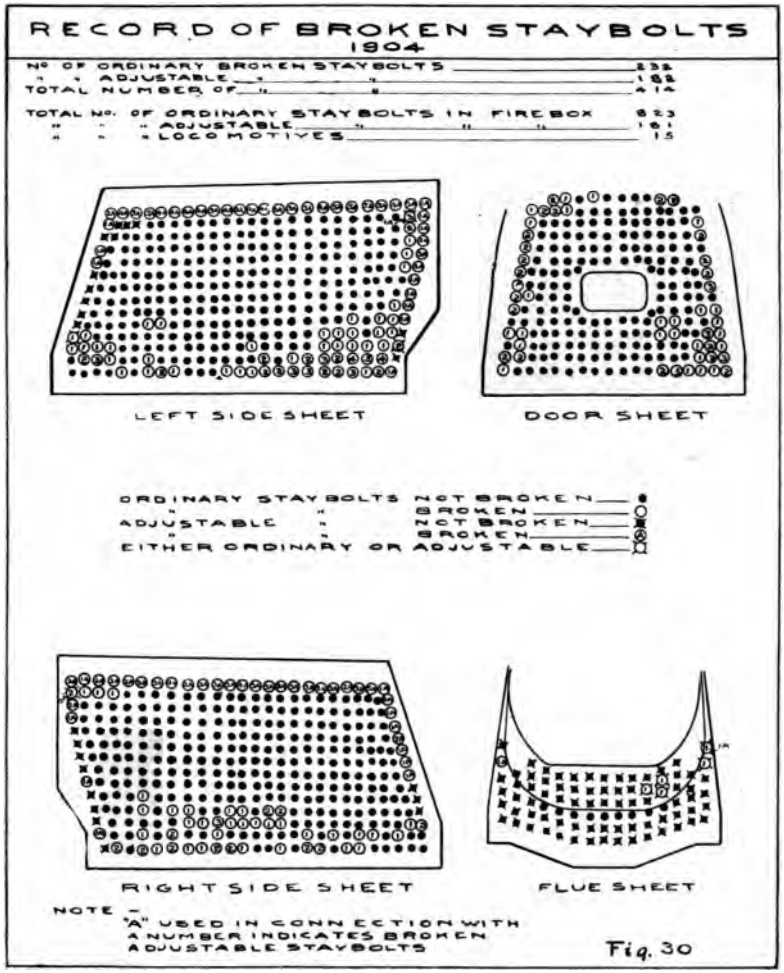

RECORD OF BROKEN STAYBOLTS
1904
No OF ORDINARY BROKEN STAYBOLTS 232
" " ADJUSTABLE " " 182
TOTAL NUMBER OF " " 414
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX 823
" " " ADJUSTABLE " " " 161
" " " LOCOMOTIVES 15
LEFT SIDE SHEET
DOOR SHEET
ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " NOT BROKEN
" " BROKEN
EITHER ORDINARY OR ADJUSTABLE
RIGHT SIDE SHEET
FLUE SHEET
NOTE —
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig. 30

U of M

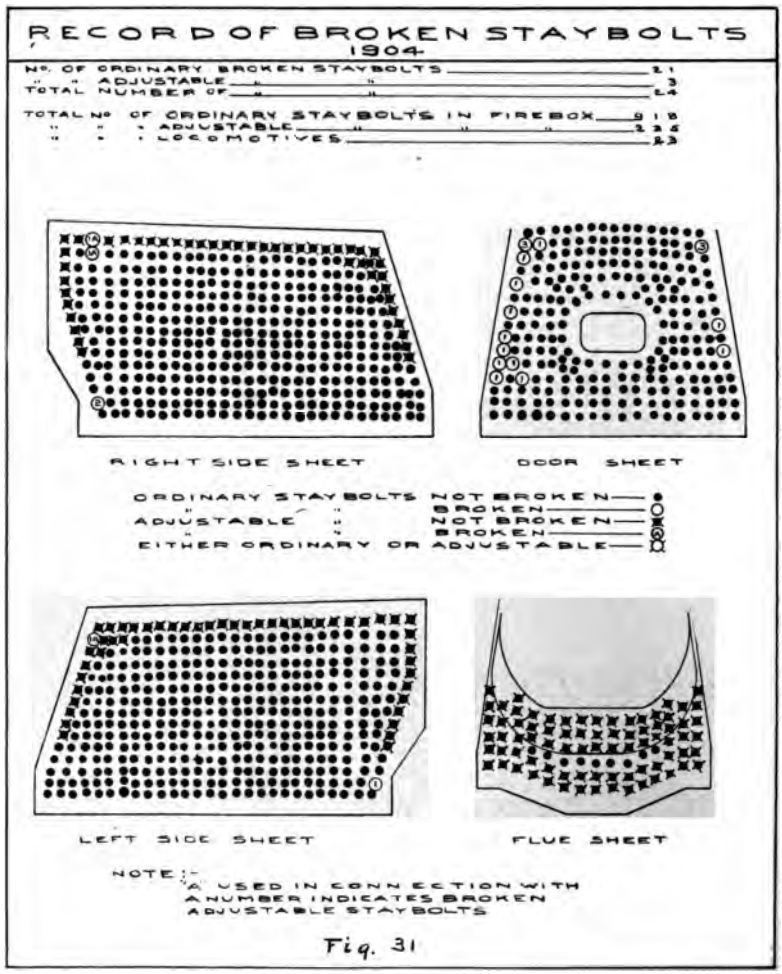

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 21
" " ADJUSTABLE " " 3
TOTAL NUMBER OF " " 24
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 918
" " " ADJUSTABLE " " " 325
" " LOCOMOTIVES 1243
RIGHT SIDE SHEET
DOOR SHEET
ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " NOT BROKEN
" " BROKEN
EITHER ORDINARY OR ADJUSTABLE
LEFT SIDE SHEET
FLUE SHEET
NOTE:-
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig. 31

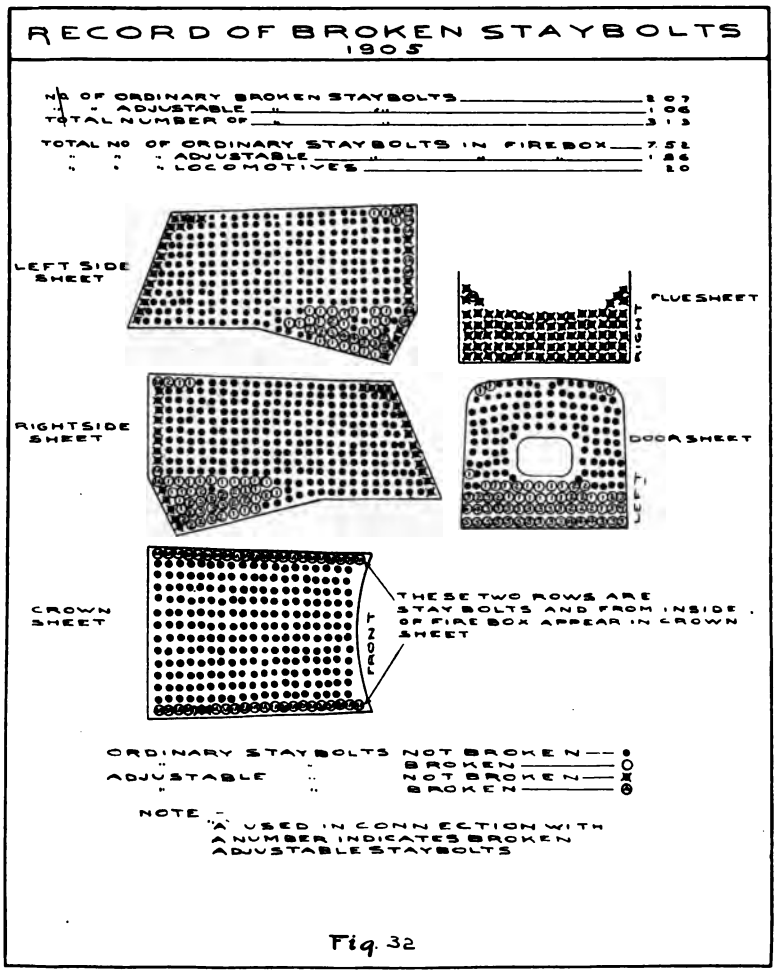

RECORD OF BROKEN STAYBOLTS
1905
No OF ORDINARY BROKEN STAYBOLTS 807
" " ADJUSTABLE " " 106
TOTAL NUMBER OF " " 913
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 7521
" " " ADJUSTABLE " " " 1246
" " " LOCOMOTIVES 210
LEFT SIDE SHEET
FLUE SHEET
RIGHTSIDE SHEET
DOOR SHEET
CROWN SHEET
THESE TWO ROWS ARE STAY BOLTS AND FROM INSIDE OF FIRE BOX APPEAR IN CROWN SHEET
ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " NOT BROKEN
" " BROKEN
NOTE -
"A" USED IN CONNECTION WITH A NUMBER INDICATES BROKEN ADJUSTABLE STAYBOLTS

Fig. 32

U of M

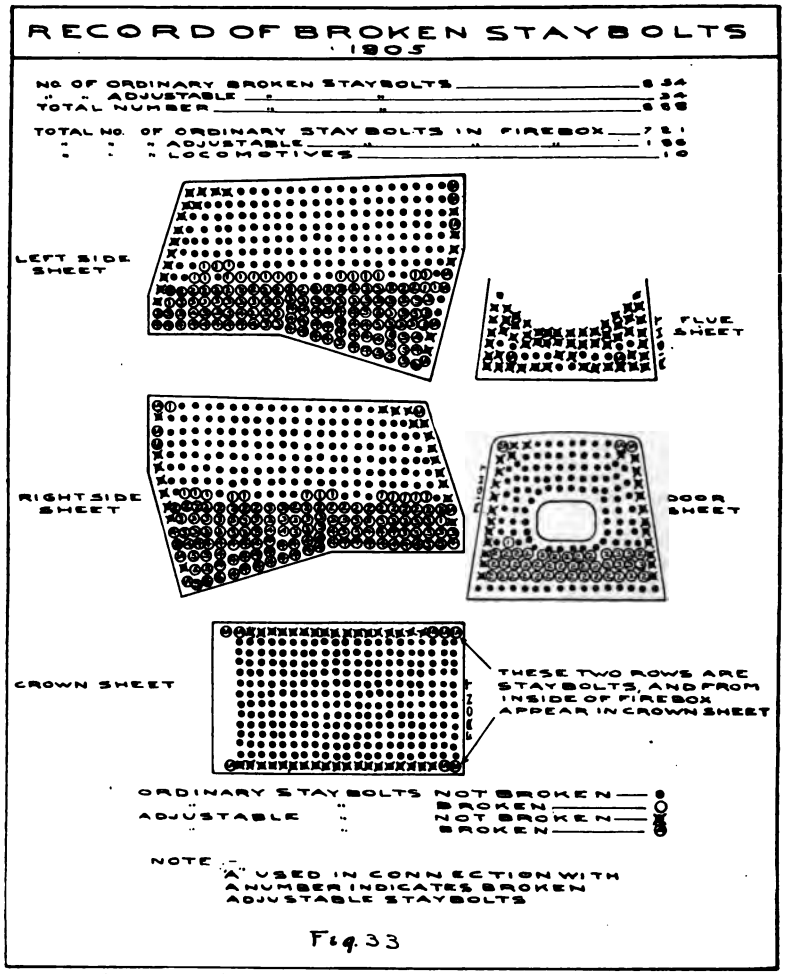
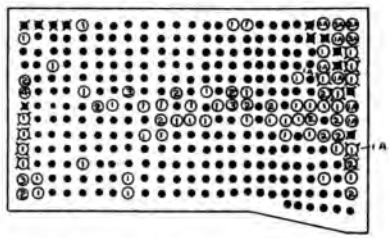

RECORD OF BROKEN STAYBOLTS
1905
NO. OF ORDINARY BROKEN STAYBOLTS 6 54
" " ADJUSTABLE " " 34
TOTAL NUMBER " " 6 88
TOTAL NO. OF ORDINARY STAYBOLTS IN FIREBOX 7 21
" " " ADJUSTABLE " " " 1 96
" " " LOCOMOTIVES 10
LEFT SIDE SHEET
FLUE SHEET
RIGHT SIDE SHEET
DOOR SHEET
CROWN SHEET
THESE TWO ROWS ARE STAYBOLTS, AND FROM INSIDE OF FIREBOX APPEAR IN CROWN SHEET
ORDINARY STAYBOLTS NOT BROKEN 8
" " BROKEN 0
ADJUSTABLE " NOT BROKEN 3
" " BROKEN 4
NOTE:- "A" USED IN CONNECTION WITH A NUMBER INDICATES BROKEN ADJUSTABLE STAYBOLTS

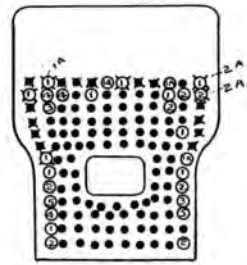
Fig. 33

RECORD OF BROKEN STAYBOLTS
1904

No OF ORDINARY BROKEN STAYBOLTS	217
" " ADJUSTABLE " "	34
TOTAL NUMBER OF " "	261
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX	7447
" " " ADJUSTABLE " " "	82
" " " LOCOMOTIVES	71

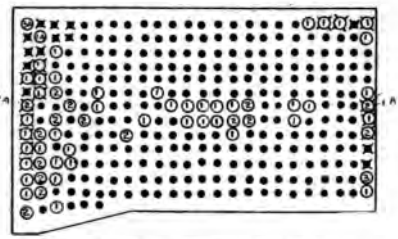


LEFT SIDE SHEET

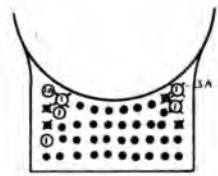


DOOR SHEET

ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " NOT BROKEN
" " BROKEN
EITHER ORDINARY OR ADJUSTABLE



RIGHT SIDE SHEET



FLUE SHEET

NOTE —
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig. 34

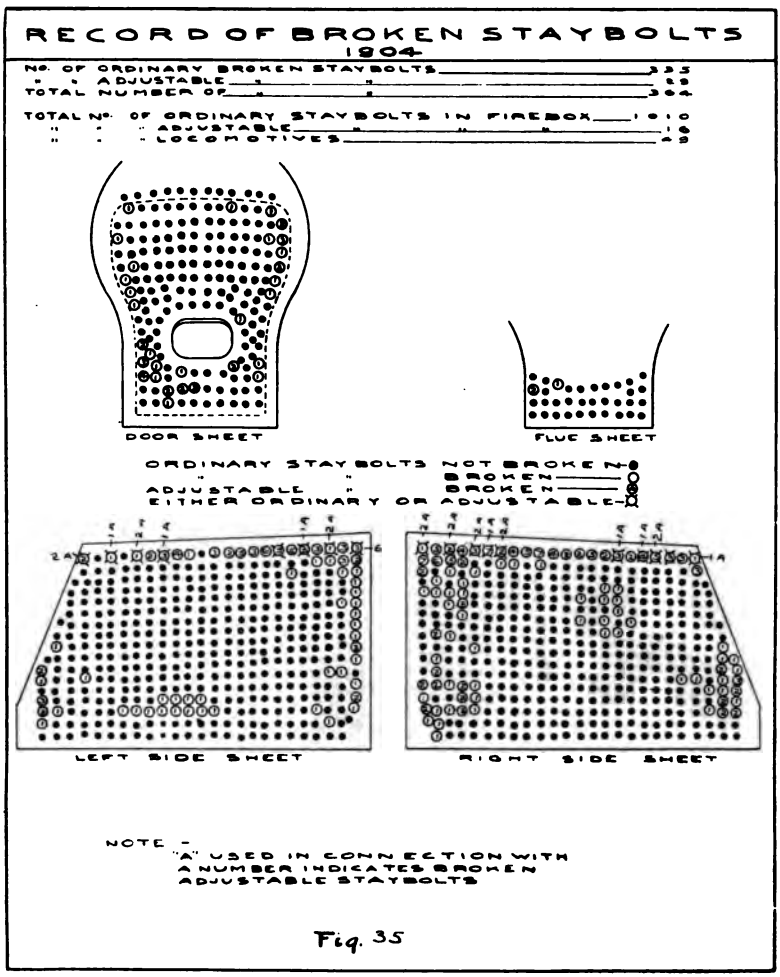

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 335
" " ADJUSTABLE " " " 29
TOTAL NUMBER OF " " " 364
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX 1810
" " " ADJUSTABLE " " " 186
" " " LOCOMOTIVES 29
DOOR SHEET
FLUE SHEET
ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " BROKEN
EITHER ORDINARY OR ADJUSTABLE
LEFT SIDE SHEET
RIGHT SIDE SHEET
NOTE -
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig. 35

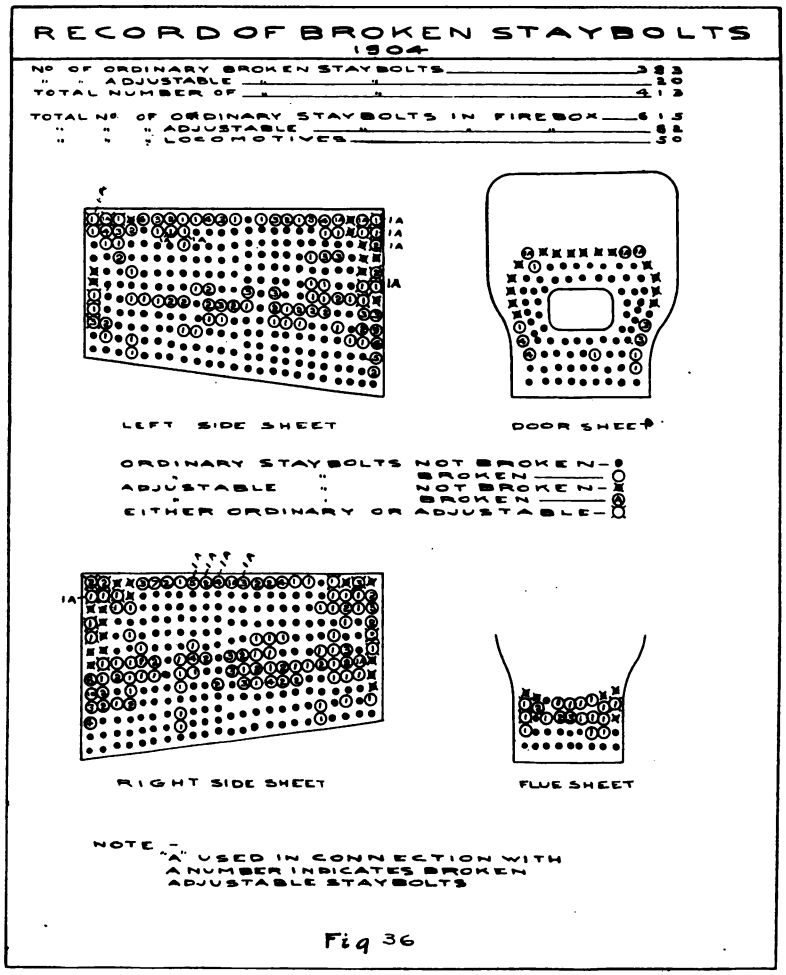

RECORD OF BROKEN STAYBOLTS
1904
No OF ORDINARY BROKEN STAYBOLTS 3 3
" " ADJUSTABLE " " 2 0
TOTAL NUMBER OF " " 4 1 3
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 6 1 5
" " " ADJUSTABLE " " " 8 2
" " " LOCOMOTIVES 5 0
1A
1A
1A
1A
LEFT SIDE SHEET
DOOR SHEET
ORDINARY STAYBOLTS NOT BROKEN
" BROKEN
ADJUSTABLE " NOT BROKEN
" BROKEN
EITHER ORDINARY OR ADJUSTABLE
1A
RIGHT SIDE SHEET
FLUE SHEET
NOTE -
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig 36

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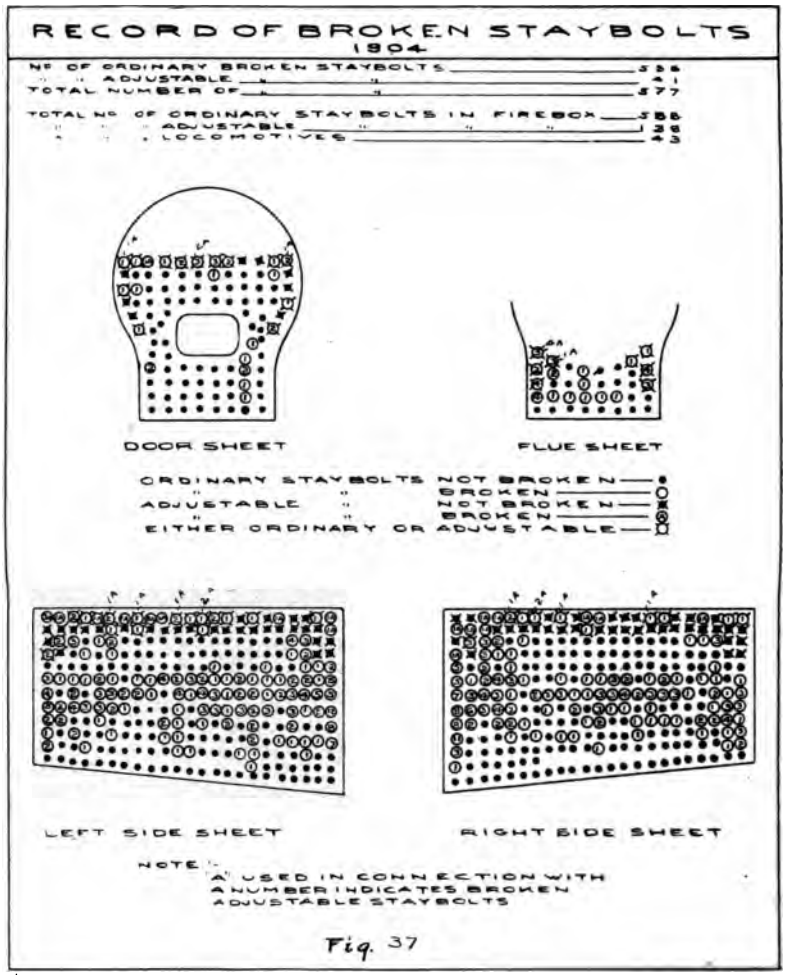
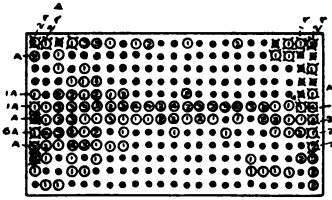

RECORD OF BROKEN STAYBOLTS
1904
No OF ORDINARY BROKEN STAYBOLTS 58
" " ADJUSTABLE " " 1
TOTAL NUMBER OF " " 577
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 388
" " " ADJUSTABLE " " " 36
" " LOCOMOTIVES 43
DOOR SHEET
FLUE SHEET
ORDINARY STAYBOLTS NOT BROKEN
" BROKEN
ADJUSTABLE " NOT BROKEN
" BROKEN
EITHER ORDINARY OR ADJUSTABLE
LEFT SIDE SHEET
RIGHT SIDE SHEET
NOTE:-
A USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig. 37

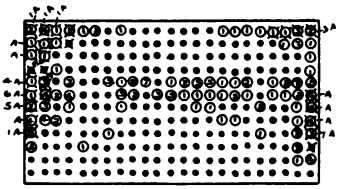
RECORD OF BROKEN STAYBOLTS

19 04

No. OF ORDINARY BROKEN STAYBOLTS	5 1 3
" " ADJUSTABLE " "	1 5 0
TOTAL NUMBER OF " "	6 6 3
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX	5 8 5
" " ADJUSTABLE " "	6 5
" " LOCOMOTIVES	7

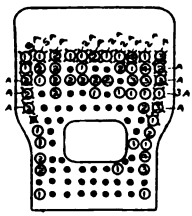


LEFT SIDE SHEET

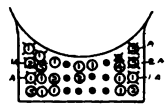


RIGHT SIDE SHEET

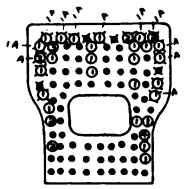
ORDINARY STAYBOLTS NOT BROKEN —
" " BROKEN —
ADJUSTABLE " NOT BROKEN —
" " BROKEN —
EITHER ORDINARY OR ADJUSTABLE —



DOOR SHEET



FLUE SHEET



DOOR SHEET

NOTE —
"A" USED IN CONNECTION WITH A NUMBER INDICATES BROKEN ADJUSTABLE STAYBOLTS

Fig. 38

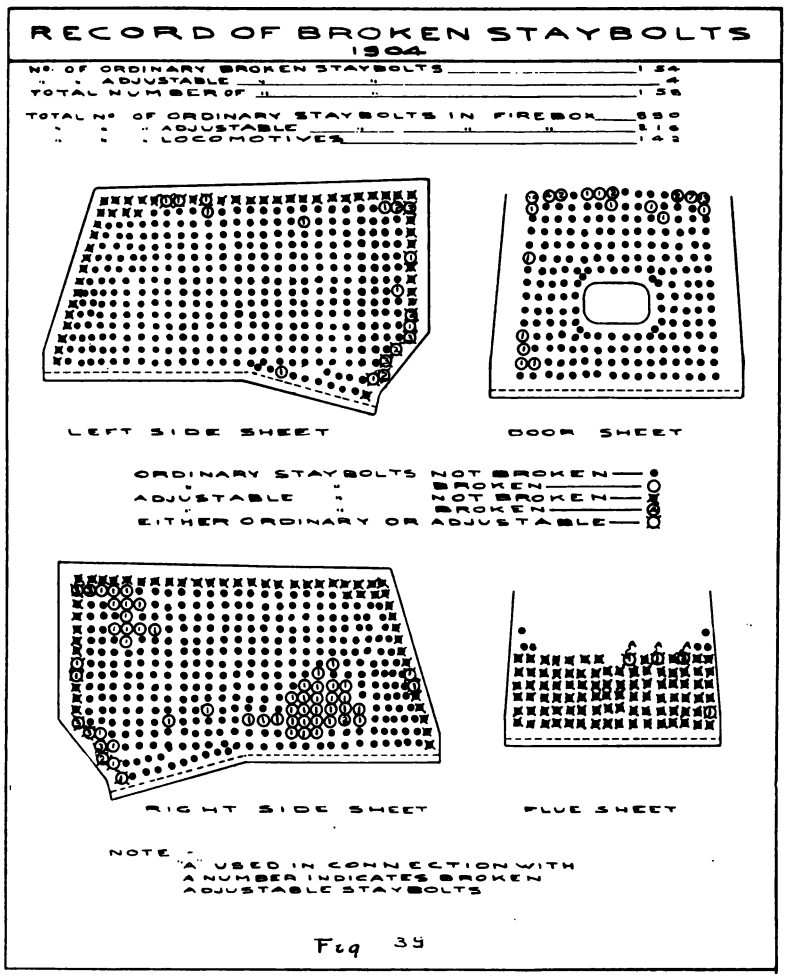

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 154
" " ADJUSTABLE " " 4
TOTAL NUMBER OF " " 158
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 830
" " " ADJUSTABLE " " " 510
" " " LOCOMOTIVES 1405
LEFT SIDE SHEET
DOOR SHEET
ORDINARY STAYBOLTS NOT BROKEN
" " BROKEN
ADJUSTABLE " NOT BROKEN
" " BROKEN
EITHER ORDINARY OR ADJUSTABLE
RIGHT SIDE SHEET
FLUE SHEET
NOTE -
"A" USED IN CONNECTION WITH
A NUMBER INDICATES BROKEN
ADJUSTABLE STAYBOLTS

Fig 35

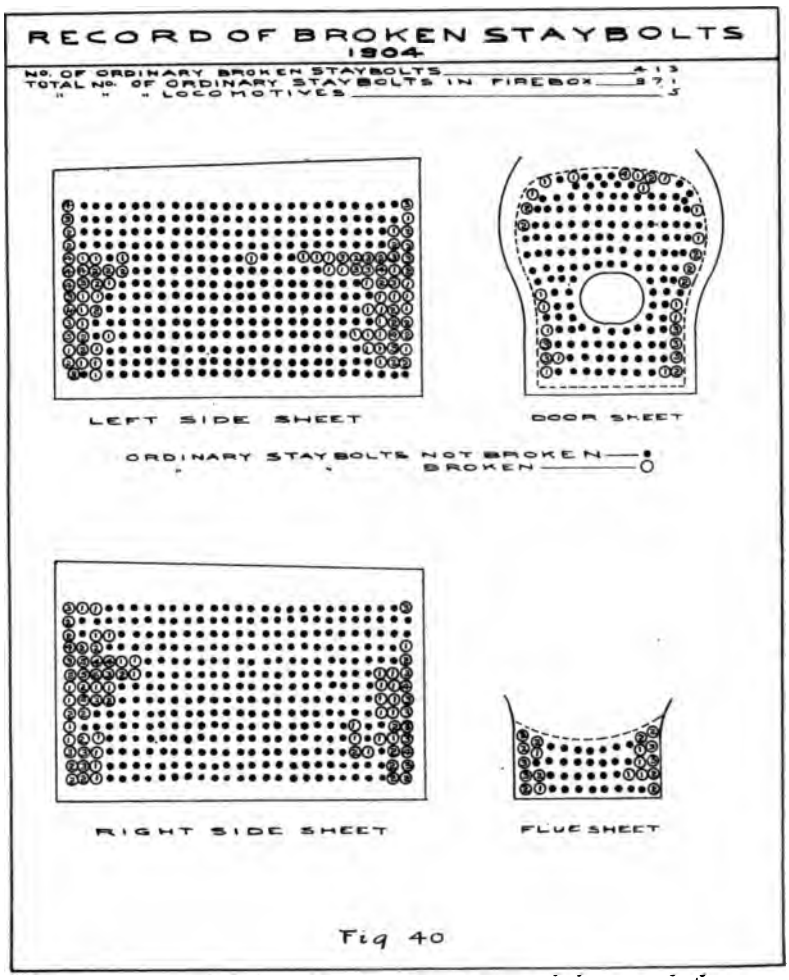

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 413
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX 971
" " " LOCOMOTIVES 3
LEFT SIDE SHEET
DOOR SHEET
ORDINARY STAYBOLTS NOT BROKEN
BROKEN
RIGHT SIDE SHEET
FLUE SHEET

Fig 40

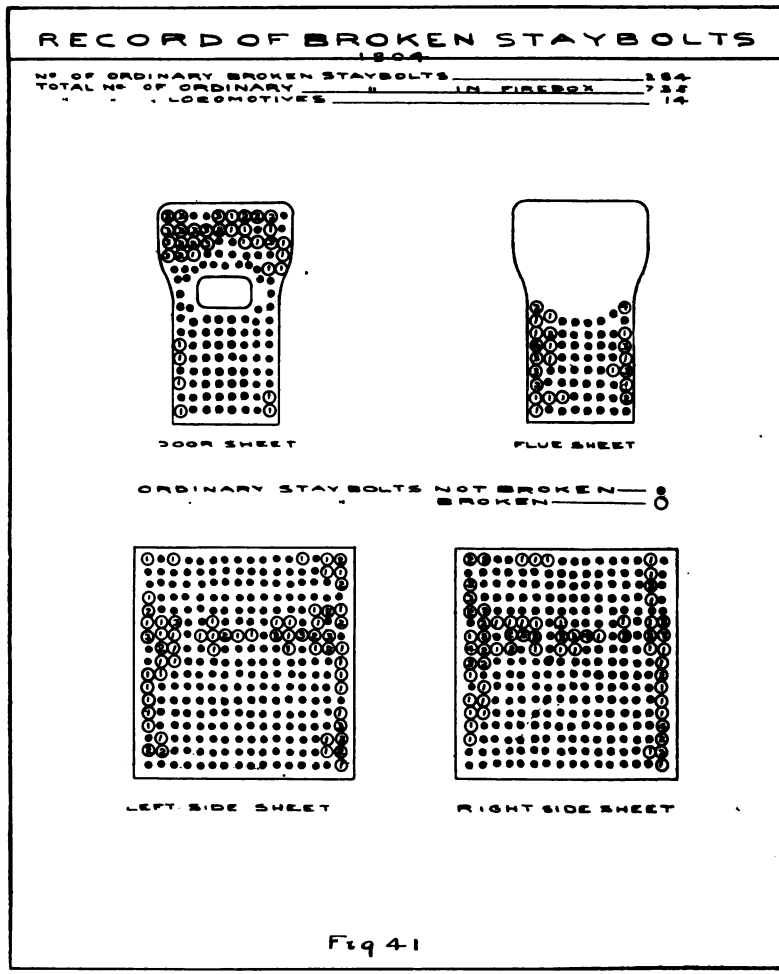

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 384
TOTAL No. OF ORDINARY " IN FIREBOX 735
" " " LOCOMOTIVES 14
DOOR SHEET
FLUE SHEET
ORDINARY STAYBOLTS NOT BROKEN
BROKEN
LEFT SIDE SHEET
RIGHT SIDE SHEET

Fig 41

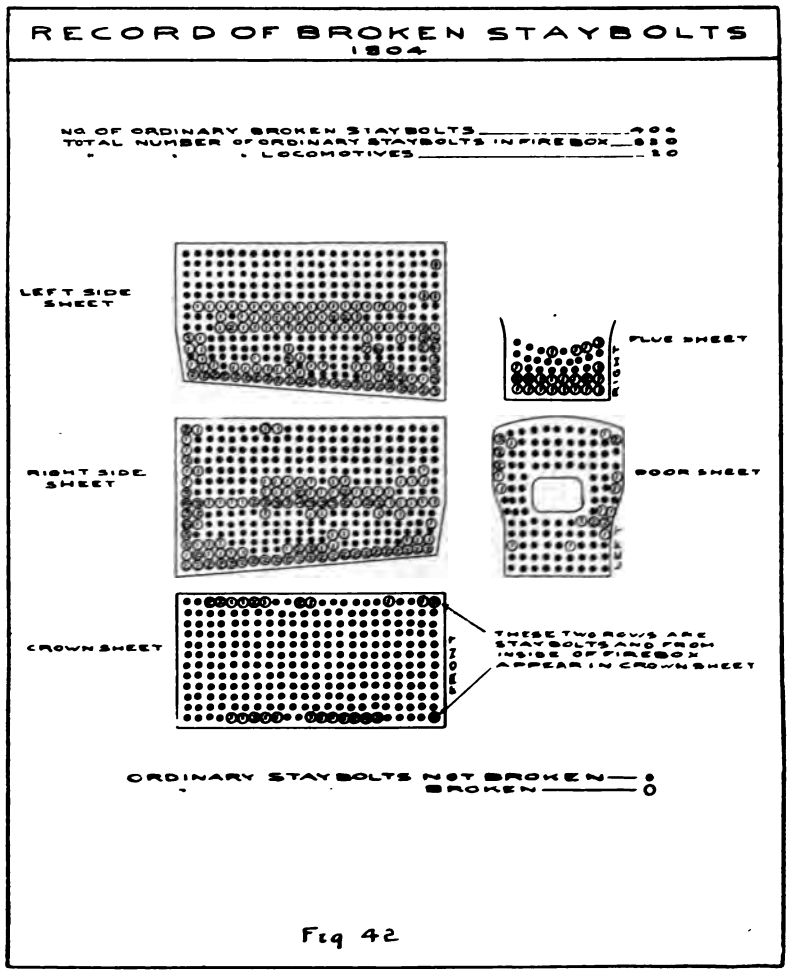

RECORD OF BROKEN STAYBOLTS
1904
NO OF ORDINARY BROKEN STAYBOLTS ---- 40
TOTAL NUMBER OF ORDINARY STAYBOLTS IN FIRE BOX --- 810
" " " LOCOMOTIVES ---- 10
LEFT SIDE SHEET
FLUE SHEET
RIGHT SIDE SHEET
DOOR SHEET
CROWN SHEET
THESE TWO ROWS ARE STAYBOLTS AND FROM INSIDE OF FIREBOX APPEAR IN CROWN SHEET
ORDINARY STAYBOLTS NOT BROKEN — 8
BROKEN — 0

Fig 42

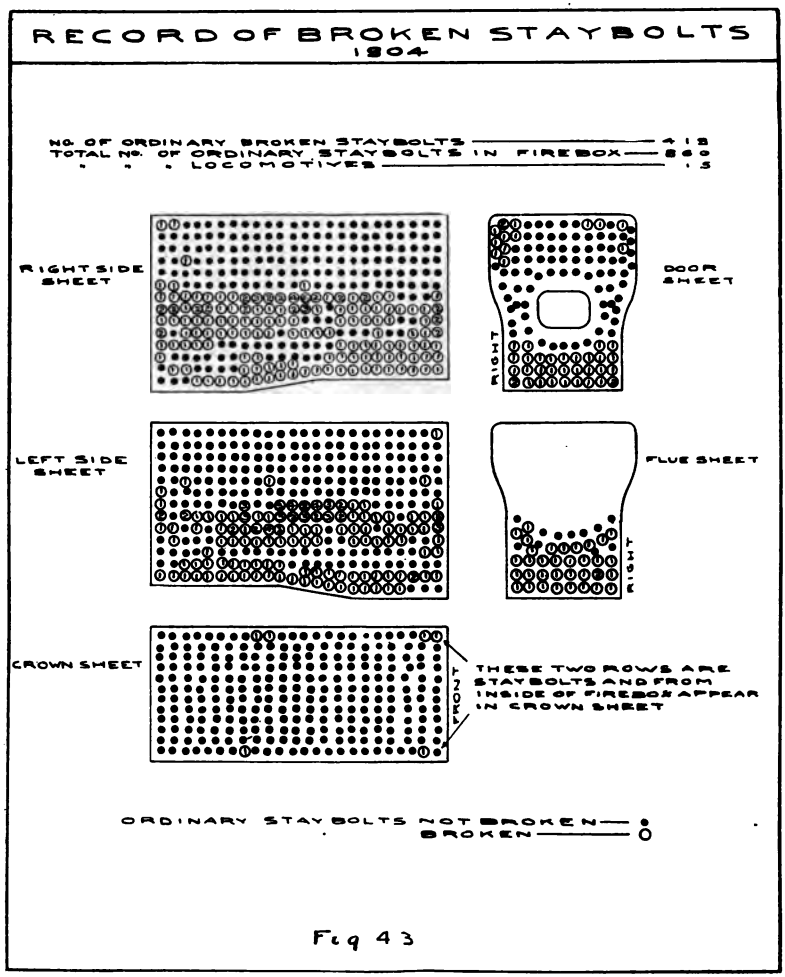

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS ——— 418
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX ——— 840
" " " LOCOMOTIVES ——— 15
RIGHT SIDE SHEET
DOOR SHEET
RIGHT
LEFT SIDE SHEET
FLUE SHEET
RIGHT
CROWN SHEET
FRONT
THESE TWO ROWS ARE STAYBOLTS AND FROM INSIDE OF FIREBOX APPEAR IN CROWN SHEET
ORDINARY STAYBOLTS NOT BROKEN — •
BROKEN ——— O

Fig 43

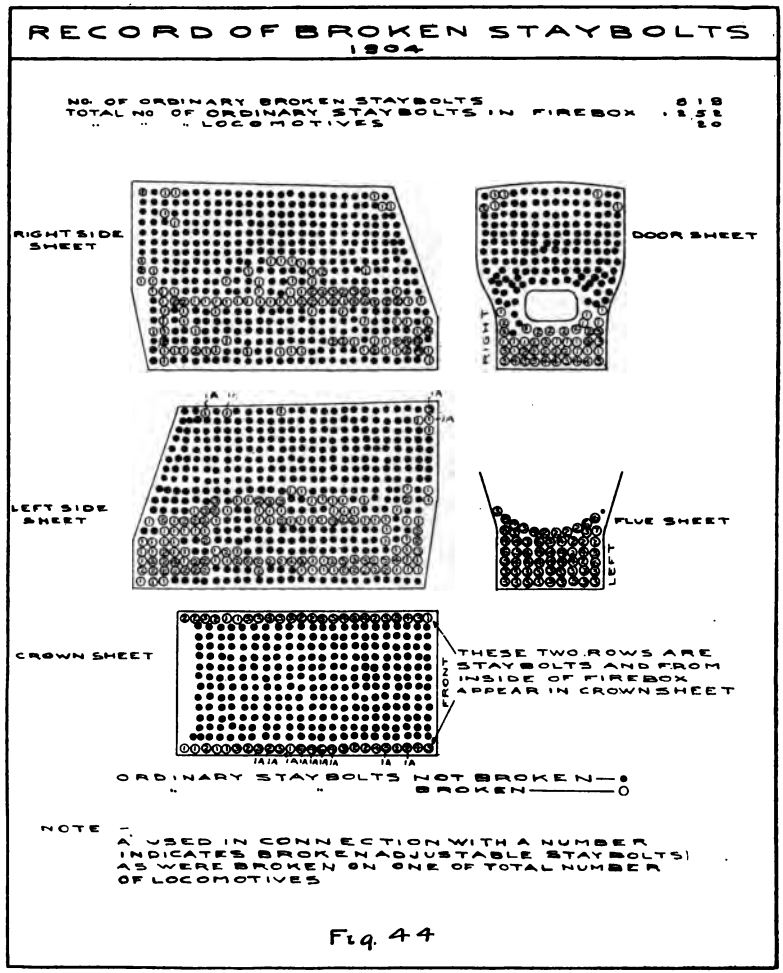

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 618
TOTAL No OF ORDINARY STAYBOLTS IN FIREBOX 12,512
" " " LOCOMOTIVES 20
RIGHT SIDE SHEET
DOOR SHEET
RIGHT
LEFT SIDE SHEET
FLUE SHEET
LEFT
CROWN SHEET
FRONT
THESE TWO ROWS ARE STAYBOLTS AND FROM INSIDE OF FIREBOX APPEAR IN CROWN SHEET
ORDINARY STAYBOLTS NOT BROKEN—•
" " BROKEN———0
NOTE —
A USED IN CONNECTION WITH A NUMBER INDICATES BROKEN ADJUSTABLE STAYBOLTS AS WERE BROKEN ON ONE OF TOTAL NUMBER OF LOCOMOTIVES

Fig. 44

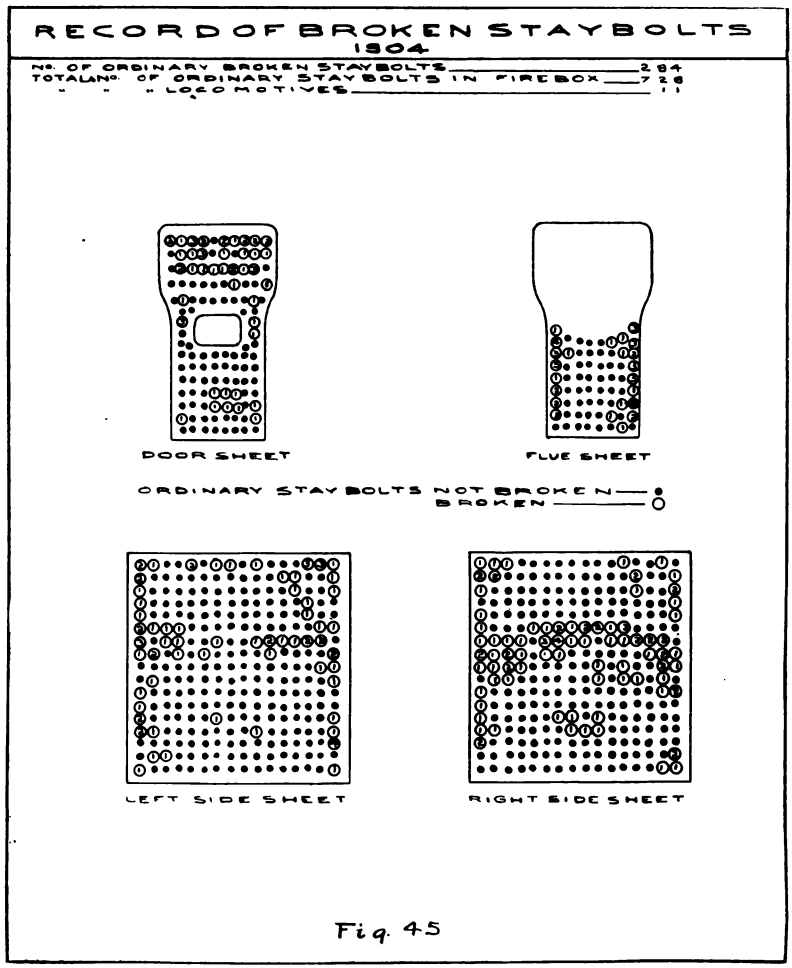

RECORD OF BROKEN STAYBOLTS
1904
No. OF ORDINARY BROKEN STAYBOLTS 284
TOTAL No. OF ORDINARY STAYBOLTS IN FIREBOX 7268
" " " LOCOMOTIVES 11
DOOR SHEET
FLUE SHEET
ORDINARY STAYBOLTS NOT BROKEN
BROKEN
LEFT SIDE SHEET
RIGHT SIDE SHEET

Fig. 45

to break up, yet the only action that takes place between the bolt and sleeve is of a grinding nature, which at the most will keep but a small space around the bolt clear, and any movement beyond the average demanded of the bolt will not be met.

In such varieties of bolts that use the flat head, incrustation will surely produce a solid bolt if conditions are favorable, the time depending on the amount of clearance between the bolt head and cap, for water and steam get past the seat of the bolt and sleeve, depositing such salts as may be contained. With the spherical-headed bolts this cause of rigidity may be overcome or lessened, for, theoretically, all the clearance required by this form is anything less than actual contact and, practically, enough to provide for irregularities due to manufacture. It is safe to assume that this amount of clearance will always be present, due to vibration and movement of the bolts.

There has been a small amount of trouble that neither of the above forms provide for, namely, if scale is deposited above the head of the bolt, no provision is made for taking care of expansion of the bolt and approaching of the sheets, which has been known to result, with sleeves using brass caps, in the forcing out of the center of the cap. It is evident that the amount of trouble resulting from incrustation depends entirely upon the amount of solid matter contained in the water and whether it deposits as a hard or soft scale.

The fact that there is a movement of the fire box and outer sheets has always been recognized, but what this movement amounts to and the direction it takes appears to have been known only in a vague and indefinite way, an investigation of a thorough character having apparently, from a careful research by your committee, never been conducted. Considering the different sheets that form the fire box of the boiler as plane surfaces, expansion of these sheets takes place in two different planes, one in a plane containing the sheets that may be under consideration, and the second in a plane perpendicular to these sheets, it being a separation or approaching of the inner and outer sheets of the boiler. In an investigation the individual expansion of each sheet is of no definite value, for if both the inner and outer sheets move the same amount in the same direction, no change of position of the stay bolt would take place, but if the expansion of each sheet occurred in opposite directions the movement of the bolt would be greatest. From this it is seen that all that concerns the bolt is the relative movement of the inner sheet with respect to the outer.

The expansion of the two sheets in their own plane, which, for convenience, may be called horizontal, is due to the changes of temperature, but the expansion in the other direction, which may be called the vertical expansion, is due to a combination of forces, among which are the expansion of the stay bolts, the buckling tendency due to the expansion of the sheets in a horizontal plane being confined to a certain extent by the stay bolts and other fastenings, and the separating force exerted by the steam pressure.

In order to obtain definite information that would give the amount and

direction of these movements, your committee conducted such experiments that would give this information, and though all data desired were not obtained, yet definite results were accomplished. Starting with the idea of determining only the relative movement of the two sheets, an apparatus, Fig. 46, was devised, consisting of a casing, containing parts making steam-tight joints, screwed in the outer sheet and a plug screwed in the inner sheet. Driven on this plug was a length of seamless steel tubing at the free end of which was attached a brass cap, the brass cap being free to slide against a half-round ring, provided to guard against the non-alignment of holes in inner or outer sheets, and so as either sheet moved in the horizontal plane a steam joint was always kept. Resting on the half-round ring and kept in contact with it by means of a spring under proper compression, was a ground piston capable of being moved up or down, obtaining by this means a steam joint if any movement in this direction took place. These three joints thus provided for any movement whatever that might take place. To provide for the relative movement of the sheets, the table for holding the papers on which the records were made was attached to the casing held by the outer sheet, and the recording levers were connected to the plug fastened in the inner sheet by means of a rod entirely free of all restraining pressures. For the movement of the sheets in a horizontal plane, a pantagraph of usual construction with a ratio at the pencil of approximately eight times the movement at the moving point, and for the vertical movement a simple lever also with a ratio of approximately eight to one, were used.

In addition to the information given by this apparatus the temperatures of the fire box and the outer sheet should be known and an attempt was made to obtain this data, but, due to the difficulties encountered, the attempt resulted in failure. The method tried for obtaining this information for the outer sheet was by drilling a small hole half through the sheet and resting the thermometer in it after it had been filled with oil, and with this but slight difficulty was encountered, the real trouble occurring with the measurement of the temperature of the fire box sheet. For this a hole was drilled the whole length of the plug fastened to the inner sheet and as near to the outer edge as possible, so that the temperature-measuring device could be adjusted to the middle of the sheet and be as near the sheet as possible, this being the best that could be done.

For the measurement of temperature a pyrometer of the Le Chatellier type was used, and as this depends upon the temperature causing a difference of potential at the juncture of two dissimilar metals it is necessary that the wires leading from this juncture shall be effectually insulated, and it was this feature that caused the abandonment of this portion of the work, for the wires leading to the galvanometer passed through the tube protecting the rod operating the recording levers, and any insulating material used had to withstand the action of high temperature, steam and hot water — very severe conditions.

The only difficulty outside of taking the temperature of the two sheets was the trouble experienced in making steam-tight joints. The moving

DELPAIRE BOILER

CROWN SHEETS

Boiler Water 63°F
Feed Water 68°
Atmosphere 78°

Fire Started 2:00 P.M.
Fire — Heavy and even

Reading	Time	Pressure	Movement								Remarks
			Horizontal				Vertical				
			Location of Device								
			1	2	3	4	1	2	3	4	
1	3:15	0	00015	00759	01951		00243	01230	01476		Steaming
2	28	15		00886		00126	00243	01353	00123	00492	Blower on
3	30	25									
4	36	55			00365			00861	00369		
5	40	85				00633		00492			
6	44	115	00861	00759	00975	00759	00731	00492	00738		
7	47	145			00487	00506	00731	00738	00246	01230	
8	49	175	02214		03609	00759	00975				Blower off 200#
9	52	205	00369	01012	00243	00506		00984			Pop blowing
10	4:02	205			00487	00759	02350				
11	04	205									Throttle open 3 notches
12	18	195	00246		00975				00492	00615	Two gauges Water used
13	19	205		01265		02151					Injector on-half open
14	27	160	00984	01139	00731		00365				Water at 3rd gauge
15	32	205									
16	35	205		00759	00365			00246	01476		Fire door open
17	40	205		00633		00633				00246	
Total			05289	06511	07188	06832	05638	06996	03520	02583	
5	5:05	205									Fire out Throttle open
1	20	0	00864	02530	00243	03160	02927	01975	01358	02091	Blow off cock opened
2			03209	03544	06585	02910	00731	01728	02716	00861	Boiler cold
Total			04073	06074	06828	06070	03658	03703	04074	02952	

BELPAIRE BOILER
SIDE SHEETS

Boiler Water 62°F
Feed Water 66°
Atmosphere 71°

Fire Started 1:35 PM.
Fire Medium

Reading	Time	Pressure	Movement								Remarks
			Horizontal				Vertical				
			Location of Device								
			5	6	7	8	5	6	7	8	
1	2:30	0	00243				00369	00609			Steaming
2	40	15									Blower started
3	45	25						00365			
4	50	55	00609	00369				00609			All devices leaking slightly
5	53	85	00243	00369			00492	00609			
6	56	115	00365	00615							
7	3:00	145	00609	01230			00369	00853			
8	04	175	01097	00615							Blower reduced
9	08	205		02091							Blower off at 3:06 - 200#
10	18	205									Pop blowing ten minutes
11	23	205									Throttle open 3 notches Two gauges
12	34	205									Water used
13	36	205									Injector on
14	42	170									
15	49	205									Door open
16	54	205									
17	56	205									Throttle open no attempt made to
18	4.05	150									keep pressure up
19	19	205	00975	02214	00379	00379	00492	00609	00369	00492	
Total			04141	05303	00379	00379	01722	03654	00369	00492	
5	4.30	200									Fire out Throttle opened
1	52	0	04141					01484			Blow off cock opened
2				02952							Water out
3					00379	00379	00984	00243	00369	00492	Boiler Cold
Total			04141	02852	00379	00379	00984	01727	00369	00492	

DELPAIRE BOILER

BACK HEAD

Boiler Water 61.5° F
Feed Water 74°
Atmosphere 81°

Fire Started 1:10 PM
Fire Not very heavy even all over

Reading	Time	Pressure	Movement								Remarks
			Horizontal				Vertical				
			Location of Device								
			9	10	11	12	9	10	11	12	
1	2:10	0									Steaming
2	15	15									Blower on
3	35	25									
4	40	55									
5	57	85									
6	3:02	115									
7	07	145									
8	09	175				00755					#11 Leaking slightly
9	11	205									Blower off at 200#
10	16	205									Pop blowing
11	20	205									Throttle open 5 notches Blower partly on
12	30	182									
13	33	205									Injector on until water showed at 3rd gauge
14	38	170									
15	48	205									Door open Pop blowing for 5 minutes.
16	53	205	00492	01518	00975	00283	00487	00738	00246	00615	
Total			00492	01518	00975	01012	00487	00738	00246	00615	
5	4:15	200									Fire out. Throttle opened
1	30	0	00369	00253	00731	00379	00487	00738	00246	00615	Blow off cock opened
Total			00368	00253	00731	00379	00487	00738	00246	00615	

Belpaire Boiler

Throat Sheets

Boiler Water 66°F
Feed Water 72°
Atmosphere 77.5°

Fire Started 1:03 PM
Fire Even and medium

Reading	Time	Pressure	Movement						Remarks
			Horizontal			Vertical			
			Location of Device						
			13	14	15	13	14	15	
1	2:40	0	00975						Steaming
2	51	15							Blower on
3	59	25							
4	3:05	55							All devices leaking slightly
5	09	85							
6	13	115	00731						
7	16	145							
8	20	175	00243						
9	23	205	00243						Blower off at 200#
10	33	205	00243						Pop blowing ten minutes
11	37	205							Throttle open 3½ notches Two gauges
12	47	203							Water used
13	48	205							Injector on till water appeared at
14	53	155							third gauge
15	4:07	205							Door open Pop blowing 5 minutes
16	12	205	00365						Fire rather dead in back
17	14	205							Throttle open - 1 gauge water used
18	16	195							
19	24	160							Injector on 8 minutes - 1 gauge Water
20	30	205		00759	00492	00738	00369	00609	
Total			02800	00759	00492	00738	00369	00609	
5	4:44	200							Fire out Throttle open
1	5:07	0							Blow off cock opened
2			00609	00506	00984	00738	00246	00487	Water out
Total			00609	00506	00984	00738	00246	00487	

Crown Sheets

Boiler Water 60°F
Feed Water 65°
Atmosphere 73.5

Fire Started 8:45 a.m.
Fire Medium growing somewhat lighter at close

Reading	Time	Pressure	Movement						Remarks
			Horizontal			Vertical			
			Location of Device						
			F	M	B	F	M	B	
1	10:20	0	.01898						Steam appears
2	35	25				00861		00246	Blower on. "M" leaking
3	43	55	00885			00984			
4	50	85	.01265	00253	00609	.00615	00369	00369	
5	58	115	00633	00506	00365	00492	01107		
6	11:05	145		00633	01728	00492			
7	11	175	.02530		00487		00492		
8	18	205	.00379	02024		00492			Blower off at 200"
9	28	205			01484		00246	.00861	Throttle open 3½ notches
10	38	180	00379	02530			00246		
11	45	205							Injector on full for 2 gauges water
12	51	170	00885	00379				00246	
13	12:06	205							Door open
14	.11	205					00861	00984	
Total			08854	06325	04673	03936	03321	02706	
S	12:26	200							Fire out Throttle open
1	45	0	.03415	00759	04210	00984		02337	Blow off cock opened
2	1:28		.01012	02650			02091	01107	Water out
3			.05063		00487	02460		02583	Boiler cold
Total			09490	03409	04697	03444	02091	06027	

Radial Stay Boiler

Side Sheets

Boiler Water 60.5°F
Feed Water 77°
Atmosphere 86°

Fire Started 1:05 P.M.
Fire — Medium

Reading	Time	Pressure	Movement								Remarks
			Horizontal				Vertical				
			Location of Device								
			5	6	7	8	5	6	7	8	
1	2:15	0					00738	00369			Steaming
2	30	15					00492				Blower on
3	44	25					00615	00492			#8 Leaking
4	50	55	00365				00615				
5	56	85	00243					01230			
6	3:02	115	00487	00633			00984	00369			
7	05	145									
8	09	175		00506			00615	00738			
9	13	205	01119	01265			00861	00738			Blower off at 200#
10	23	205						00615			Pop blowing 10 minutes
11	26	205					00369	00738			Throttle open 2½ notches – 2 gauges
12	42	180					00246	00492			Water used Blower on
13	44	205									Injector on full Blower on
14	49	160					00984	00861			Water at 3rd gauge
15	57	205									Door open
16	4:02	205	00482	00506	00492	01139			00972	00738	
Total			02695	02910	00492	01139	06519	06742	00972	00738	
S	4:25	200									Fire out Throttle open
1	5:43	0	01972	00885	00492	01012					Blow off cock open
2			01097				02829	02091	00487	00738	Water and steam out
Total			03069	00885	00492	01012	02829	02091	00487	00738	Boiler Cold

RADIAL STAY BOILER
BACK HEAD

Boiler Water 63°F
Feed Water 76°
Atmosphere 83°

Fire Started 1:15PM
Fire — Heavy and even

Reading	Time	Pressure	Movement								Remarks
			Horizontal				Vertical				
			Location of Device								
			9	10	11	12	9	10	11	12	
1	2:30	0					00365				Steaming
2	50	15									Blower on
3	54	25									
4	3:02	55					00243				
5	08	85									
6	12	115									
7	16	145									
8	20	175						00492			
9	23	205									Blower of at 200#
10	33	205			00731						Pop blowing 10 minutes
11	38	205			00975			00246			Throttle open 3½ notches – 2 gauges Water Orge. press. 187#
12	50	190									
13	55	205									Injector on – Water to 3rd gauge
14	4:01	155									
15	14	205					00609				Door open
18	19	205	01107	00633	00853	00759			00615	00369	
Total			01107	00633	02559	00759	01217	00738	00615	00369	
5	4:42	200									Fire out Throttle open
1	5:05	0									Blow off cock open
2	53				00609	00379			00738	00492	Water out
3			00615	00379			00609	00369			Boiler Cold
Total			00615	00379	00609	00379	00609	00369	00738	00492	

RADIAL STAY BOILER

THROAT SHEET

Boiler Water 64°F
Feed Water 75°
Atmosphere 79.5°

Fire Started 1:50 P.M.
Fire – Heavy

Reading	Time	Pressure	Movement						Remarks
			Horizontal			Vertical			
			Location of Device						
			13	14	15	13	14	15	
1	2:40	0							Steaming
2	55	15							Blower on
3	3:02	25							
4	10	55							
5	14	85							
6	19	115							
7	23	145							
8	26	175							
9	29	205	00379						Blower off at 200#
10	39	205							Pop blowing 10 minutes
11	42	205							Throttle open 2 notches – 2 gauges of Water
12	4:01	180	02278						
13	03	200							Injector on Blower used
14	08	170							Water at 3rd gauge
15	11	205							Door open
16	16	205							Pop blowing 5 minutes
17	18	205							Throttle open 2 notches for 7 minutes
18	25	160							Injector on full 3 minutes Avge Pres. 190#
19	32	205		00506	00487	01107	01107	00738	
Total			02657	00506	00487	01107	01107	00738	
5	4:45	205							Fire out, Throttle open
1	5:20	0							Blow off cock opened
2	6:10								Water out
3			01012	00506	00487	01230	00861	00984	Boiler cold
Total			01012	00506	00487	01230	00861	00984	

EXPLANATION OF MOVEMENT DIAGRAMS

(FIGURES 49 TO 56)

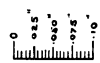
FOR LOCATION OF POINTS SEE FIGS. 45-46

DIAGRAMS REPRESENT MOVEMENT OF A POINT ON INSIDE SHEET WITH RESPECT TO THE CORRESPONDING POINT ON OUTSIDE SHEET.

CARDS ON LEFT SIDE OF SHEET REPRESENT MOVEMENT IN PLANE OF BOILER SHEET. CARDS ON RIGHT SIDE REPRESENT SEPARATION OF THE TWO BOILER SHEETS.

UPPER CARDS OF EACH SET ARE THOSE TAKEN WHILE BOILER WAS HEATING. LOWER CARDS THOSE WHILE COOLING.

THE SCALES BELOW ARE FOR USE IN SCALING DIMENSIONS FROM THE MOVEMENT DIAGRAMS AND WILL GIVE THE TRUE MOVEMENT OF THE SHEETS.



SCALE FOR MULTIPLIER 8.2

SCALE FOR MULTIPLIER 7.9

SCALE FOR MULTIPLIER 8.1

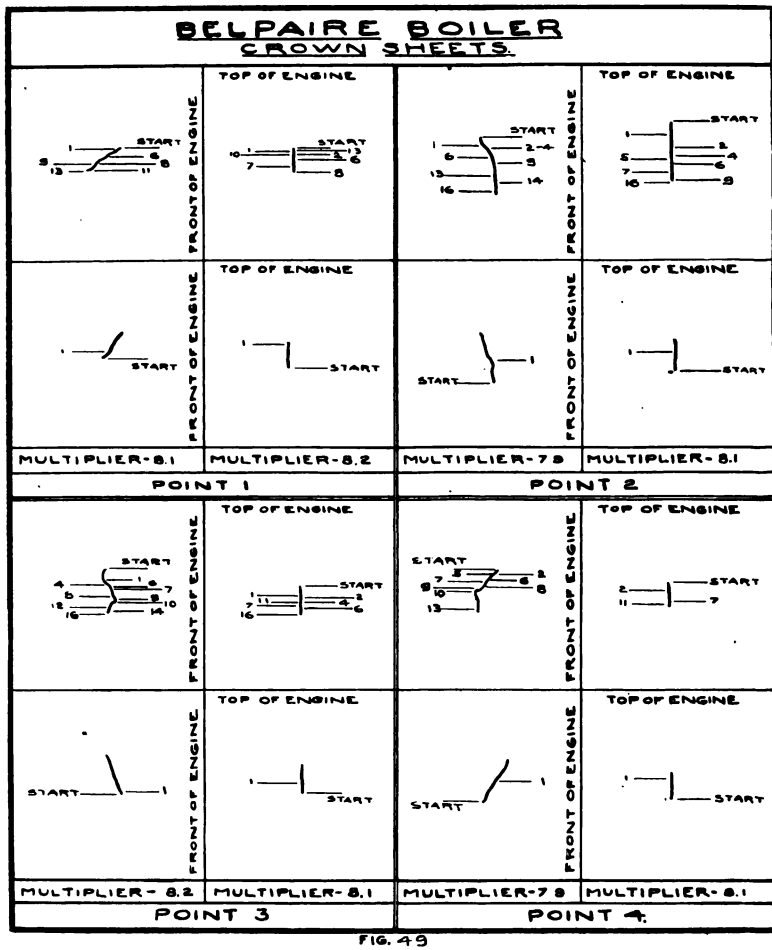

BELPAIRE BOILER
CROWN SHEETS
TOP OF ENGINE
FRONT OF ENGINE
START
MULTIPLIER-8.1
MULTIPLIER-8.2
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 1
POINT 2
MULTIPLIER-8.2
MULTIPLIER-8.1
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 3
POINT 4

FIG. 49

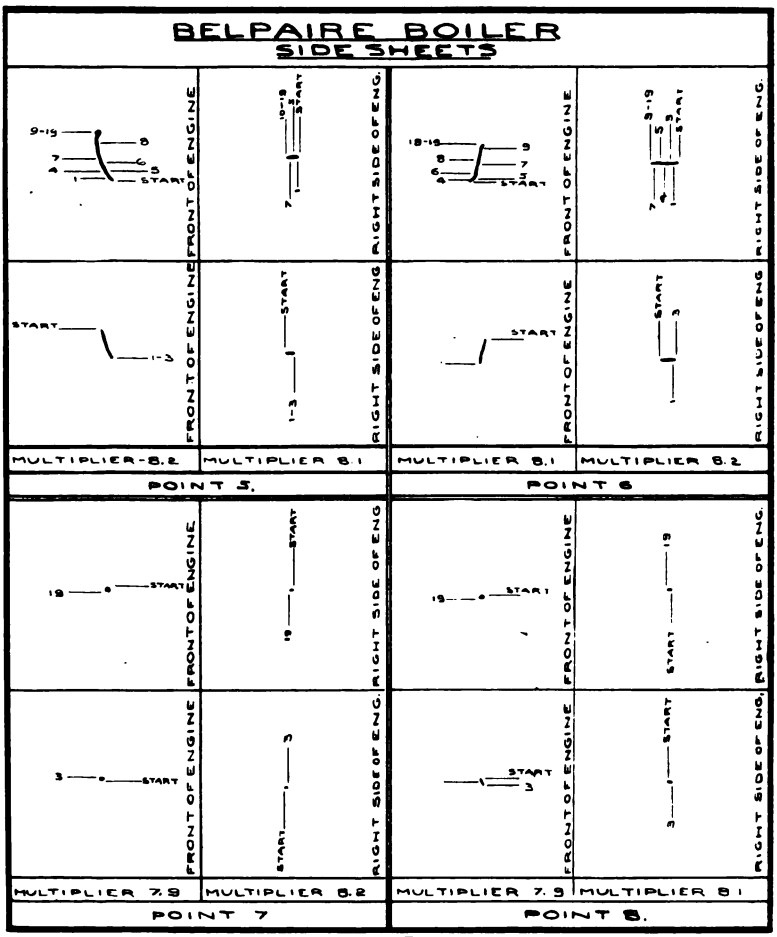

BELPAIRE BOILER
SIDE SHEETS
FRONT OF ENGINE
RIGHT SIDE OF ENG.
MULTIPLIER-8.2
MULTIPLIER 8.1
POINT 5.
MULTIPLIER 8.1
MULTIPLIER 8.2
POINT 6
MULTIPLIER 7.9
MULTIPLIER 8.2
POINT 7
MULTIPLIER 7.9
MULTIPLIER 8.1
POINT 8.

FIG. 50

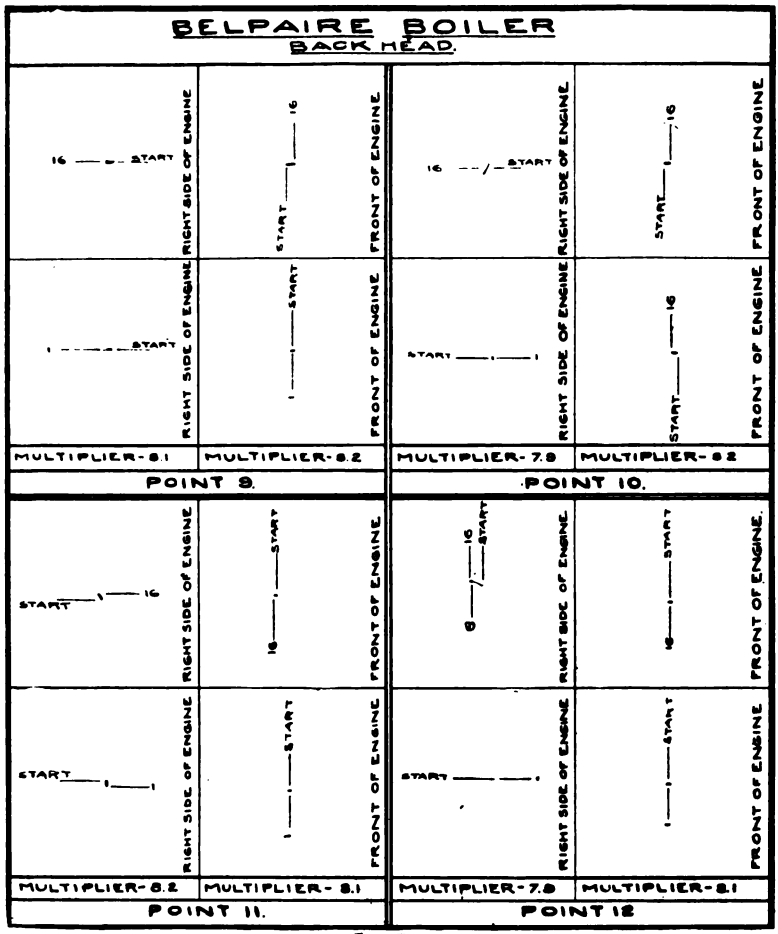

BELPAIRE BOILER
BACK HEAD.
POINT 9.
MULTIPLIER-8.1
RIGHT SIDE OF ENGINE
16
START
MULTIPLIER-8.2
FRONT OF ENGINE
START
16
POINT 10.
MULTIPLIER-7.9
RIGHT SIDE OF ENGINE
16
START
MULTIPLIER-8.2
FRONT OF ENGINE
START
16
POINT 11.
MULTIPLIER-8.2
RIGHT SIDE OF ENGINE
START
16
MULTIPLIER-8.1
FRONT OF ENGINE
START
16
POINT 12
MULTIPLIER-7.9
RIGHT SIDE OF ENGINE
8
16
START
MULTIPLIER-8.1
FRONT OF ENGINE
16
START

FIG. 51

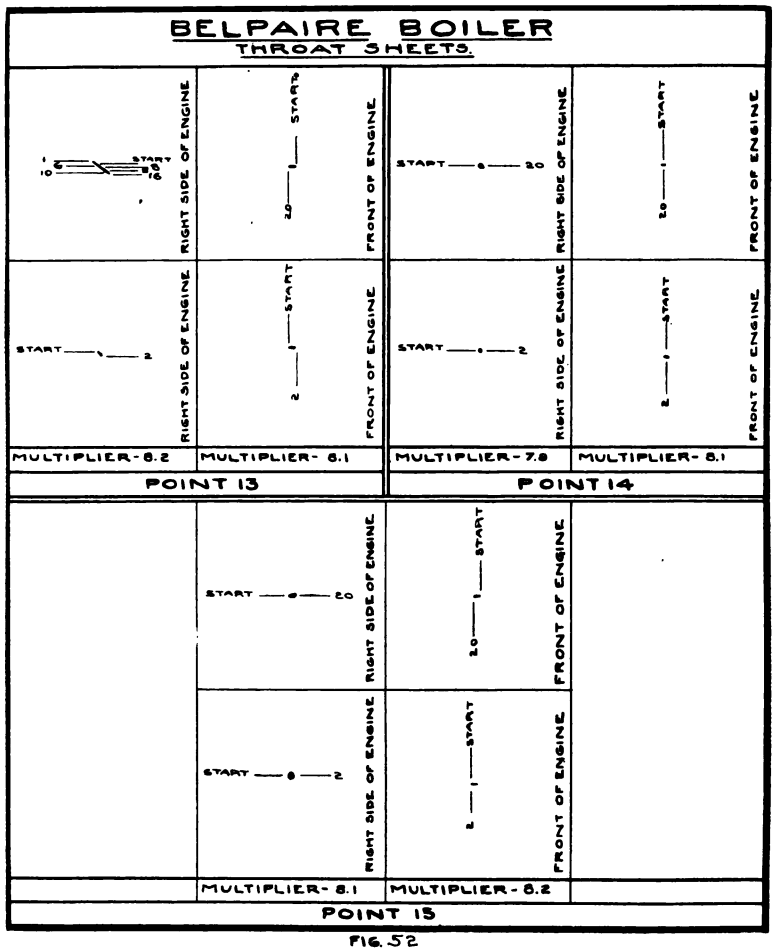

BELPAIRE BOILER
THROAT SHEETS.
RIGHT SIDE OF ENGINE
FRONT OF ENGINE
START
MULTIPLIER- 8.2
MULTIPLIER- 8.1
MULTIPLIER- 7.8
MULTIPLIER- 8.1
POINT 13
POINT 14
MULTIPLIER- 8.1
MULTIPLIER- 8.2
POINT 15

FIG. 52

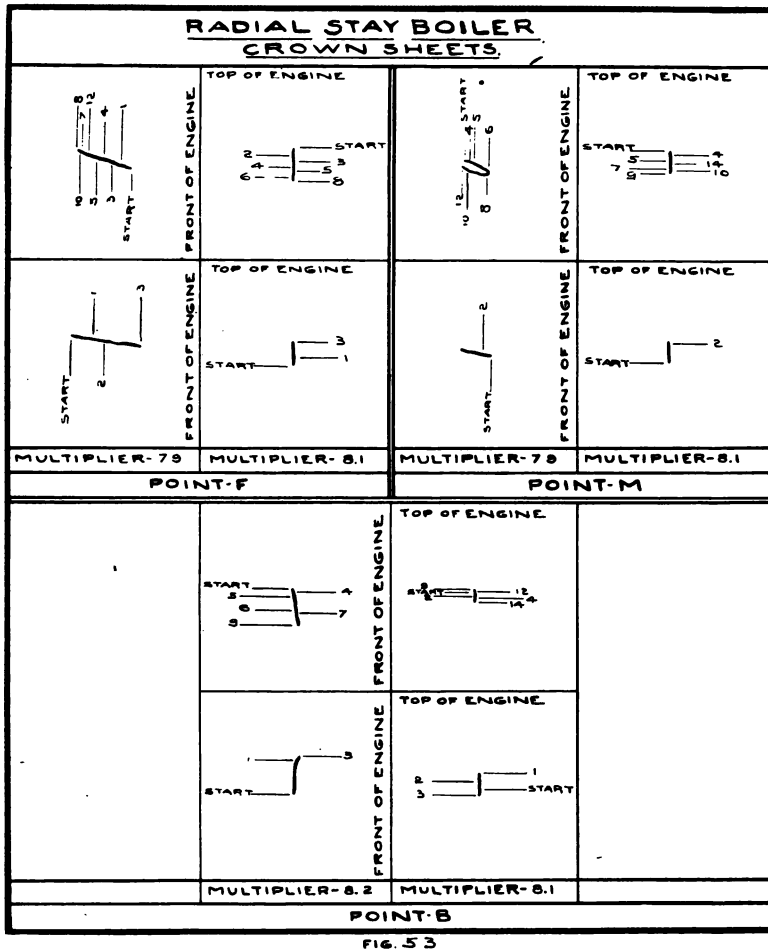

RADIAL STAY BOILER
CROWN SHEETS.
TOP OF ENGINE
FRONT OF ENGINE
START
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT-F
POINT-M
MULTIPLIER-8.2
POINT-B

FIG. 53

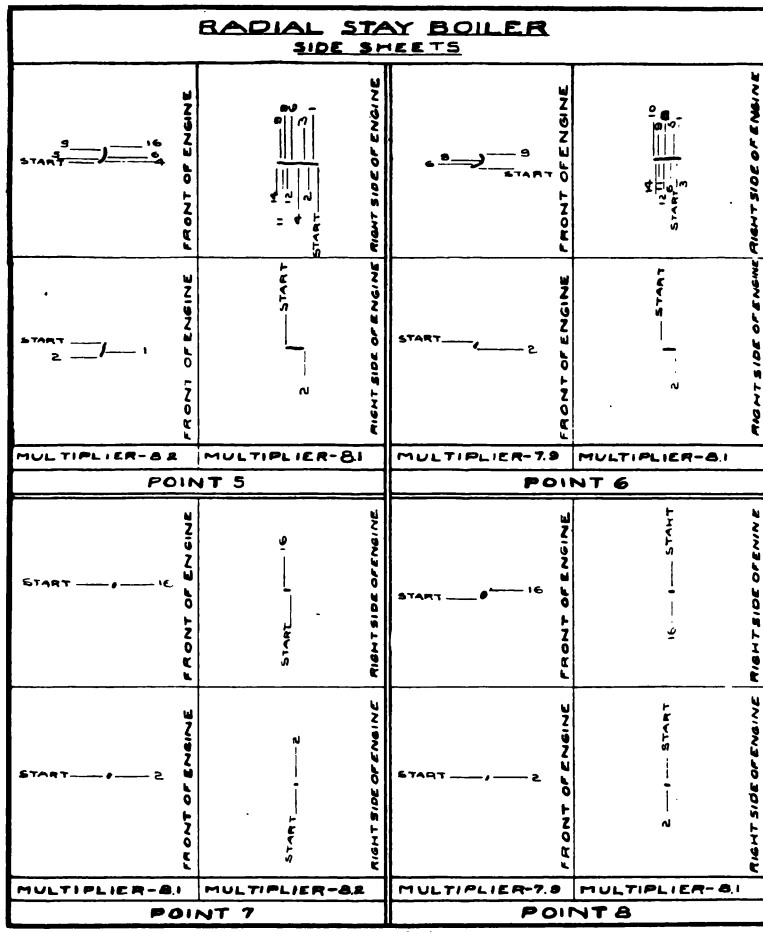

RADIAL STAY BOILER
SIDE SHEETS
FRONT OF ENGINE
RIGHT SIDE OF ENGINE
START
MULTIPLIER-8.2
MULTIPLIER-8.1
POINT 5
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 6
MULTIPLIER-8.1
MULTIPLIER-8.2
POINT 7
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 8

FIG 54

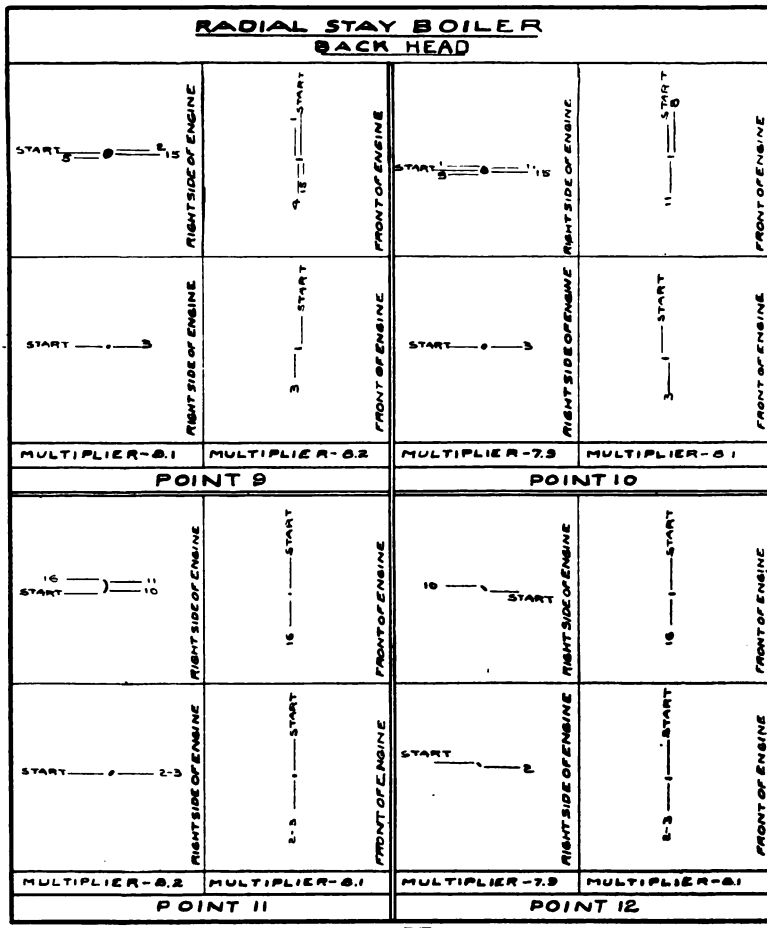

RADIAL STAY BOILER
BACK HEAD
START
RIGHT SIDE OF ENGINE
FRONT OF ENGINE
MULTIPLIER-8.1
MULTIPLIER-8.2
POINT 9
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 10
MULTIPLIER-8.2
MULTIPLIER-8.1
POINT 11
MULTIPLIER-7.9
MULTIPLIER-8.1
POINT 12

FIG. 55

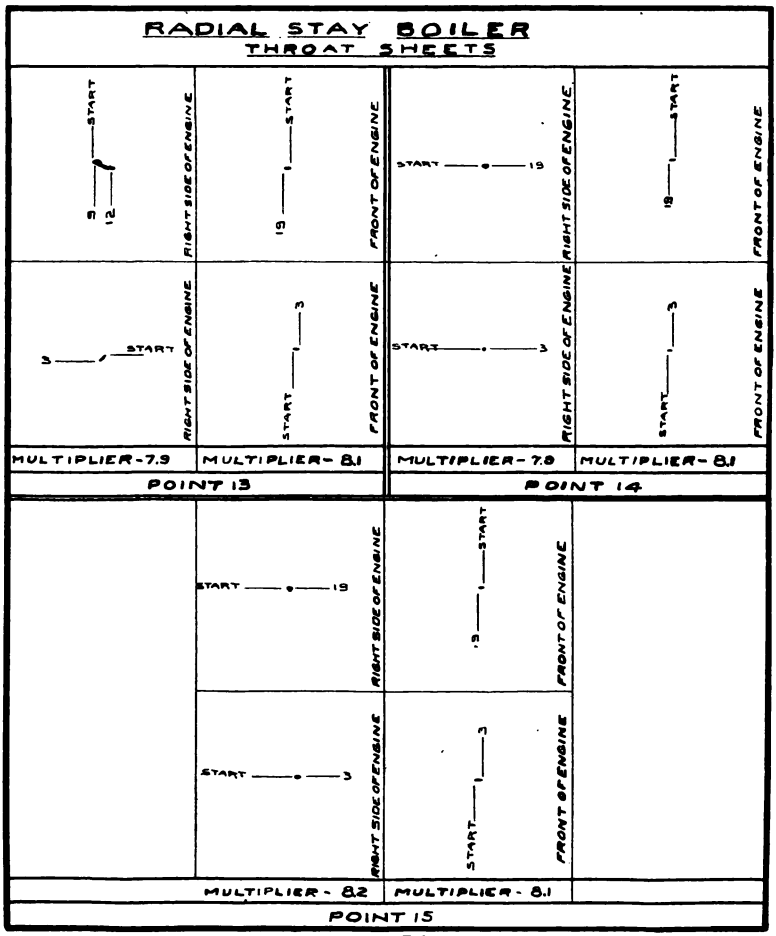

RADIAL STAY BOILER
THROAT SHEETS
START
9
12
RIGHT SIDE OF ENGINE
START
19
1
FRONT OF ENGINE
START
19
RIGHT SIDE OF ENGINE
START
18
1
FRONT OF ENGINE
START
3
RIGHT SIDE OF ENGINE
START
1
3
FRONT OF ENGINE
START
3
RIGHT SIDE OF ENGINE
START
1
3
FRONT OF ENGINE
MULTIPLIER-7.9
MULTIPLIER- 8.1
MULTIPLIER- 7.8
MULTIPLIER- 8.1
POINT 13
POINT 14
START
19
RIGHT SIDE OF ENGINE
START
1
19
FRONT OF ENGINE
START
3
RIGHT SIDE OF ENGINE
START
1
3
FRONT OF ENGINE
MULTIPLIER- 8.2
MULTIPLIER- 8.1
POINT 15

FIG. 56

place and this means the bolt has undergone a reversal of strain which, in the horizontal plane, indicates a bending action taking place. However, little of this reversing took place after the boiler was under normal pressure for ten minutes. Nevertheless it is interesting to know that the line of fracture of broken stay bolts closely agrees with the general direction taken by the sheets in expanding as indicated by the diagram, and that failure is probably due to a repetition of small movements over a long period and aided by the tension exerted by the separation of the sheets.

In conclusion, your committee believes that flexible stay bolts are giving very satisfactory service where the design is good and the conditions are favorable. The only unfavorable conditions which seriously affect the srevice are bad workmanship and water containing hard scale-forming material; the first condition being less serious than the second.

It has been shown that there is a definite movement of the sheets, of small amount, from the cold boiler to the working pressure temperature and that the movement has an effect upon the life of the bolt. Any small changes of temperature, caused by the operation of the injector, reduced steam pressure, or the opening of the fire door, produce a movement of the smallest amount.

Your committee believes that it is wise to substitute flexible bolts at the points where experience shows the greatest breakage of rigid ones, and that no hard and fast rule can be laid down to show where this occurs, as this location is affected by the design of the boiler; that the flexible bolt must be one designed to minimize the difficulty from incrustation; that it must be of proper strength and with sufficient clearance in its fittings; and finally, that the design should, if possible, be one to facilitate examination. With these conditions observed, your committee is convinced that the flexible bolts will give great relief from the present troubles.

R. N. DURBOROW, Chairman,
F. M. WHYTE,
C. E. FULLER,
O. H. REYNOLDS,
Committee.

ALTOONA, PA., June 5, 1906.

APPENDIX I.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

CIRCULAR OF INQUIRY FROM THE COMMITTEE ON FLEXIBLE STAY BOLTS.

To the Members:

The scope of the subject referred to your committee was outlined as follows:

"To consider the subject of flexible stay bolts, number in use, manner of applying and the service rendered," and to secure the information necessary for such a report, your coöperation, by answering the questions as fully as possible, is asked.

1. Are you using flexible stay bolts?

2. Have you used flexible stay bolts and later discontinued their use? If so, please give reason for such action.

3. If you are using or have ever used flexible stay bolts
   (a) Furnish names of makers of kinds used.
   (b) Furnish prints of kinds used.
   (c) Fully describe manner of applying the kinds used.

4. (a) Furnish print of boiler in which flexible stay bolts are used, and indicate steam pressure carried.
   (b) Give number of boilers equipped.
   (c) Give number of flexible stay bolts used per boiler.

5. Is the use of flexible stay bolts standard or experimental?

6. Indicate on diagram location of flexible stay bolts and points at which failure has been greatest.

7. If possible, show where the fracture of the flexible stay bolt generally occurs.

8. In case of frequent breakages of rigid stay bolts, have you tried replacing them with flexible stay bolts? If so, did the change produce definite results? Please give the conditions.

9. Have you found that the use of flexible stay bolts in the throat sheet prevented the shearing of threads in the sheet?

10. Have you experienced any trouble from incrustation on flexible stay bolts?

11. In general, in case of failure of flexible stay bolts, have you been able to assign a cause for such failure? If so, please give some of these causes.

12. Can you give any data in regard to comparative cost of maintaining fire boxes, with the rigid and flexible stay bolt?

13. Have you made any experiments to determine amount of expansion vertically and horizontally in a fire box when using steam from cold water to temperature of running pressure? If so, please give details of such experiments as thoroughly as possible.

Please send your replies and blue-prints or such information as you are able to give to Mr. R. N. Durborow, Superintendent Motive Power, Pennsylvania Railroad Co., Altoona, Pa.

R. N. DURBOROW, Chairman,
F. M. WHYTE,
C. E. FULLER,
O. H. REYNOLDS,
Committee.

THE PRESIDENT: Gentlemen, you have heard the reading of this very excellent report. It is certainly gratifying to find work being carried out by these committees in the manner in which this subject has been handled, and such an excellent report reflects very creditably on the committee.

MR. ANGUS SINCLAIR: I move the report be received and opened for discussion. (Carried.)

THE PRESIDENT: Perhaps it would be just as well for Mr. Newberry to open the discussion on the report.

MR. W. H. NEWBERRY: I hardly know what to say on the subject. I would be glad to answer any questions. One point not brought out in the report is that there is a fire box designed to do away with the flexible stay bolts, and yet give the same service. The committee considered that matter, but concluded that that was a little outside of the flexible stay bolt question and did not go into it to any extent, and for the same reason the rigid bolts designed to be used in connection with the flexible bolts were also not gone into. It was the conclusion of the committee that the flexible stay bolt gave very satisfactory service.

MR. W. H. WICKHORST (C. B. & Q.): In making these measurements of the movements of sheets, I would ask if the sheets were free from scale? Was the fire box a new one?

MR. NEWBERRY: The sheets were clean, but not new.

MR. WICKHORST: It strikes me that probably the main reason for large movements of fire-box sheets is the forming of scale

or mud, or other insulating material, on the fire-box sheet, stay bolts and flues. If the sheets and stay bolts are free from scale, the temperature can not be very much different from the temperature of the water. I made some temperature tests, which indicated that, with a hot fire, a half-inch sheet can not be raised above the temperature of the water more than 40° or 50° F., but allow ⅛ of an inch of scale to form and the temperature of the metal will rise above the temperature of the water by several hundred degrees. In fact, with a hot fire and ⅛-inch scale on the stay bolts and sheets, the sheets can probably actually attain a low red heat. As the relative movement of the sheets is probably primarily a function of the difference of temperature more than any other thing, it will be seen that if the inside sheet is allowed to become materially raised in temperature the movement is going to be greater; and I rather imagine that, if the test had been made with scaled fire-box sheets, movements would have been found. For instance, by opening the fire door after a good hot fire; with a hot fire and scaled sheets, with the temperature of the water say 400° or a little lower, the temperature of the fire box would easily be raised to 600°, 800° or 1,000°, whereas if the sheet is perfectly clean the temperature of the fire box probably would not have been raised to over 450°.

MR. G. R. HENDERSON: I do not notice anything in the report about the cost of stay bolts, and that is an important item, particularly if you have side sheets which only last a year or two in service. We can hardly afford to put in very expensive stay bolts in those sheets. I would like to have some discussion on that phase of the question.

MR. NEWBERRY: That point was considered by the committee, but not taken up, simply because the members did not submit prices, and that was the only way we had to get any data on that phase of the subject.

MR. J. F. WALSH (C. & O.): We commenced using the flexible stay bolts about three years ago on our high-pressure engines. We had a certain class of consolidation engines, long fire boxes, carrying 200 pounds of steam, which troubled us greatly. As we commenced the construction of the wide fire-box engines, we put the stay bolts in the outside rows in the side sheets, butt

sheets and additional ones up in the upper corners, and putting as many flexible stay bolts in the throat sheets as we could get in there. We probably have all told 15,000 or 16,000 flexible stay bolts in 210 or 215 engines, and up to a few days ago we had not a failure of the flexible stay bolts. However, two days ago I got a report of 22 broken flexible stay bolts removed from one of our engines which had been in service about twenty-three months. That is the first failure we had out of the 15,000.

I must say, in justice to those interested in the matter, that probably 2,500 of these 15,000 bolts are represented by Fig. 4 in the report of the committee. The balance of the 15,000 are represented by Fig. 7, and the failures we have had up to date have been exclusively those represented in Fig. 4. Outside of that we have not had a failure of a flexible stay bolt. We consider the investment an excellent one.

Referring to the matter of price, spoken of by Mr. Henderson, I would say that the type of flexible stay bolt that has failed represented a cost to us of three times more than those that have not failed. We paid for the first bolts about 90 cents each. More recently the cost of the bolt has run about 35 cents.

MR. A. E. MITCHELL: I have had experience with the flexible stay bolt of the type shown in Fig. 7, which is the only type that I have used. All of my experience has been on the Wooten type of boilers. We have introduced about 40,000 of these bolts in the last two years, and in that period we have not had a failure of that type of bolt. Previously we had a large number of failures of the rigid type in our throat sheets, and in one type of boiler we had failures frequently; but where the flexible type of bolt is used we have entirely eliminated the trouble. I am a firm believer in the flexible bolt of the type shown in Fig. 7.

MR. D. J. DURRELL (Penna. Lines West): We use the same water for our locomotives that Mr. Garstang uses through Ohio and Indiana. We have many thousands of the flexible stay bolts, illustrated in Fig. 4, in our locomotives, and we are using experimentally some of the stay bolts shown in Fig. 7. I desire to say that the question of incrustation touched upon in the report, to our minds, has a great deal to do with the failure of flexible stay bolts. Where we have installed water purifying plants I

do not think for two years we have had a failure of a flexible stay bolt, all of which, I might say, are installed practically as shown in Fig. 4. I want to say for the information of the convention — referring to Fig. 4 — that the failure of these stay bolts occurs at a point which would be on this scale a fraction of an inch, about 1/8 of an inch, below the slot in the end of the bolt; in other words, the enlarged part of the bolt forming the head breaks off at a point which would be, say, 1/8 of an inch below the slot. Otherwise we have had no failures with that type of bolt.

Mr. C. E. Fuller (C. & A. R. R.): The Chicago & Alton Railroad has from twenty-five to thirty engines equipped with various types of flexible stay bolts as described in Figs. 4, 6 and 7, some of which have been in service about four years. We have had no failures with any of these bolts, with the exception of those shown in Fig. 6, and the failure of these bolts has been due to the punching of the square countersink in the head being a little too deep, which weakened the bolts just under the head sufficiently to cause the head to pull off. With this style of bolt we have stopped countersinking the head, and we have had no failures with the bolts thus applied. Otherwise the flexible bolt has proven very satisfactory.

We have applied most of our flexible stay bolts in the first three rows from the corners in the side sheets and the three top rows below the crown sheet, and, in the wide fire-box engines, practically all the bolts in the throat sheet and the two upper rows in the back head.

Mr. G. W. Wildin (Erie): Something like seven years ago, during Mr. Mitchell's incumbency in office, the Erie applied to a locomotive some flexible bolts of the type known as the "Acme," a cut of which I do not see represented in the report, but they are quite similar to Fig. 6, eighty in all being applied. During the past year it became necessary to remove the fire box and a very close examination was made of each individual bolt, to determine its condition. Of the eighty bolts we discovered only four which showed a slight fracture — the defect was located directly under the head of the bolt and extended in depth less than half the diameter of the bolt. The record made by the eighty bolts men-

tioned led us to adopt the flexible bolt as a standard, and we are now applying them to all engines where the fire box is renewed. I presume the committee, in mentioning a certain road as applying all stay bolts of the flexible type and not trying to determine the breaking zone, has reference to the Erie, as that is the practice we are following. We have been unsuccessful in determining the breaking zone, and I am pleased to note that the committee confirms our views in this respect, as they also can not make definite recommendations along these lines. We have, therefore, taken what we call the safe course, and are applying flexible bolts to all parts of the fire box where they do not interfere with the boiler fittings. About a year ago we equipped an engine with flexible bolts of the Fig. 7 type, and I am advised by the Master Mechanic of that division that he has removed a number of the caps from bolts at various points and he has yet to find the first bolt with leakage around the head. This fire box was applied by the American Locomotive Company at their Pittsburgh works, and was evidently a very good job. I think with the short sleeve, as shown in Fig. 7, the possible trouble from corroding and incrustation will be eliminated.

MR. D. J. REDDING (P. & L. E.): We applied flexible stay bolts similar to Fig. 7 to several fire boxes about two years ago; so far, none of the flexible bolts have broken, neither have any of the rigid bolts in these boxes broken, so that we think we have the breaking zone fairly well covered. These bolts have also been applied to all new boilers purchased during the past year.

MR. WM. MCINTOSH (C. R. R. of N. J.): Mr. President, some five years ago we commenced supplying the bolt shown on page 5, Fig. 9, and with several thousand of them in service we have removed samples occasionally to determine their condition. Very recently we have discovered indications in two cases of a fracture commencing under the ball in the shank of the bolt; so it would appear from this that there is a limit to that type of bolt, although the service has been markedly superior to any that we obtained from the ordinary bolt. We are using another flexible bolt now to a considerable extent, and desiring information about it we undertook a vibratory test that, while I do not consider that

it gives accurate information, probably gives information that will be of some value, if it serves no other purpose than to lead to further investigation in that direction.

I will give you a brief statement showing how the test was conducted. It consisted essentially of putting four bolts into sheets of fire-box steel representing the inner and outer sheets of the boiler and fire box. These are spaced four inches apart, as they would be in service, the plates being of regular fire-box and boiler thickness. Between these plates we placed a spring with the equivalent power of the boiler pressure. This had a tendency to press the plates apart in about the same ratio. We clamped the outer sheets to a table and the inner sheet to a beam that was arranged to be vibrated back and forth by power, with a total of 3-32-inch movement in either direction. The beam was moved by a ram, one end of it being held by a pin connection to the table of the machine, and the other driven by a connecting rod from a crank. This movement was kept up continuously until the bolts commenced to break and until there was only one remaining. The results seemed to show that the machine worked nearly uniformly on the various samples, and the fractures that developed were due entirely to the bending action. With solid bolts they averaged more uniformly than they did with flexible bolts. There were considerable variations with the latter, but this we attribute to the different pressure that was applied to them in screwing them into the sheets.

The results as a whole were decidedly surprising. I will state briefly that the variation in the breaking points between the flexible bolt and the rigid one ranged from 7,840, the largest number that the rigid bolt stood, to 53,560, the largest number that the flexible bolt stood, under conditions as nearly the same as we could apply it. These were 1 inch bolts. The average number of vibrations which the four bolts stood before breaking is given in the following table:

VIBRATION TESTS OF 1-INCH STAY BOLTS—4¼-INCH CENTERS.

KIND OF BOLT.	AVERAGE VIBRATIONS OF FOUR BOLTS.	WHERE BROKEN.	REMARKS.
Test No. 1—Hollow bolt..	4,813	Both sheets	
Test No. 2—Hollow bolt..	3,947	Outside sheet	
Test No. 3—Solid bolt....	4,812	Outside sheet	
Teet No. 4—Solid bolt....	5,576	Outside sheet	
Test No. 5—Solid bolt....	6,935	3—Outside sheet 1—Inside sheet	
Test No. 6—Flexible bolt .	21,706	Inside sheet	
Test No. 7—Flexible bolt .	29,410	Inside sheet	One bolt not broken account being loose in sheet.
Test No. 8—Flexible bolt .	32,447	Inside sheet	One bolt not broken account being loose in sheet.

No holes were drilled in the ends of the solid bolts.

MR. W. H. DOEBLER (Wabash): Mr. President, we have had some experience with flexible stay bolts. We started about six years ago. We were not led to the use of the flexible bolt from the breaking of the solid bolt, but to overcome the difficulty in the cracking of side sheets. We adopted a bolt as shown in Fig. 6, and the arrangement of the bolts practically as shown in Figs. 15 and 16. The application of the flexible bolts raised the life of the side sheets from eleven months to an average of three years. In the six years that I had experience with the bolt mentioned I never found one of them corroded. Every bolt removed has shown a bright bearing surface. The breaking of the side sheet has shown that it has allowed the sheet to go back and forth without cramping it in any positive position. Therefore, I think the experience I have had has demonstrated that the flexible bolt is a very valuable addition in the construction of boilers.

MR. C. A. SELEY (C. R. I. & P.): I would like to say one word, Mr. President, in reference to the matter of the telltale hole, as the present status of the matter does not seem to be fully understood. As I understood this paragraph, in hearing the report read, I inferred that the use of the telltale hole in this connection was in reference to flexible bolts only, and not necessarily with regard to their use in connection with rigid bolts. I would like to ask a member of the committee if I am correct or

not, whether it is a general criticism of the telltale hole or only in reference to their use in connection with flexible bolts.

MR. NEWBERRY: The use of the telltale hole as referred to in the report, was simply meant to include flexible stay bolts and not the rigid bolts.

MR. FRANK SLATER (C. & N.-W.): Mr. President, I would like to say a few words. I have listened very attentively to the remarks made and have paid close attention to the report of the Committee on Flexible Stay Bolts; and in view of all that has been stated and of the fact that the flexible stay bolt does break, and that its life does not appear to be very long, I believe that the most satisfactory stay bolt, and the one that is most satisfactory for a railroad company to use, is the rigid stay bolt with the telltale hole. In view of the fact that the heads of flexible stay bolts do become fractured, and as they are covered over so that an inspection can not be made safely by a hammer test, because you can not hold on to the other end of it, it is not an absolutely safe bolt to use, and until such time as an absolutely safe bolt is found, I believe that the rigid stay bolt with telltale hole is the safest and cheapest bolt to use.

THE PRESIDENT: Gentlemen, we are considerably past the noon hour, when we should begin our topical discussions. We do not want to hurry up with this interesting report, but if there is no other discussion a motion to close will be in order.

MR. A. M. WAITT: I move, Mr. President, that the discussion be closed. (Carried.)

THE PRESIDENT: The first topical discussion is: "Is not a boiler pressure of 185 pounds better than 200 pounds for locomotives?" To be opened by Prof. W. F. M. Goss.

IS NOT A BOILER PRESSURE OF 185 POUNDS BETTER THAN 200 POUNDS FOR LOCOMOTIVES?

PROF. GOSS: Mr. President and Gentlemen: I assume that this question which is asked, as to whether a pressure of 185 pounds is not better than a pressure of 200 pounds for locomotive service, applies to simple locomotives using saturated steam; also that the question applies to proposed locomotives — that is, that I may discuss it as a question of design rather than a question

of expediency, controlling the operation of existing engines. Since the beginning of the practice involving locomotives the steam pressure has steadily increased. I have taken from a paper by one of our members, Mr. William Forsyth, published some time ago in the *Engineering Magazine,* a diagram which is immediately behind our First Vice-President, showing the progress in steam pressure with the years. On this diagram you will see that the 100-pound limit was passed between 1860 and 1870; the 160-pound limit was passed in 1890, and the 200-pound limit was exceeded in certain cases in 1900, and the tendency of the curve is still upward. In view of this history it is of importance to ask whether the limit of pressure has been reached; or, to word the question as it has been worded for me, as to whether the limit has not already been passed. As a preliminary to a more detailed discussion of the subject, I would call attention to the fact that as a problem in design the question of steam pressure does not directly affect the question of power. It is a common mistake to assume that a locomotive carrying an abnormally high steam pressure must be abnormally powerful. Of course, those of you who have studied the problem understand that that can not be so, or need not be so, since the power which the locomotive develops is represented by the stresses which are transmitted by the piston rods, and these stresses are as much a function of the cylinder volumes as of the steam pressure. Consequently, having selected our steam pressure, we may determine the volume of cylinders for any power which is within the capacity of the other proportions of the locomotive. The thing which I emphasize is, then, that the question of power is not related to that of pressure as a problem in design, except in so far as pressure may affect efficiency.

This leads us, then, to a consideration of the question, to what extent will increase in pressure improve the cylinder performance of a locomotive? I believe that a general view of the facts involved in this question may most easily be apprehended by referring to the performance of the ideally perfect engine, and for this reason I have given upon Diagram 2 as the curve X A B the steam consumption per h.-p. hour of an engine ideally perfect, using steam at various pressures and exhausting at a pressure of 5 pounds above atmosphere. From this diagram you will see that

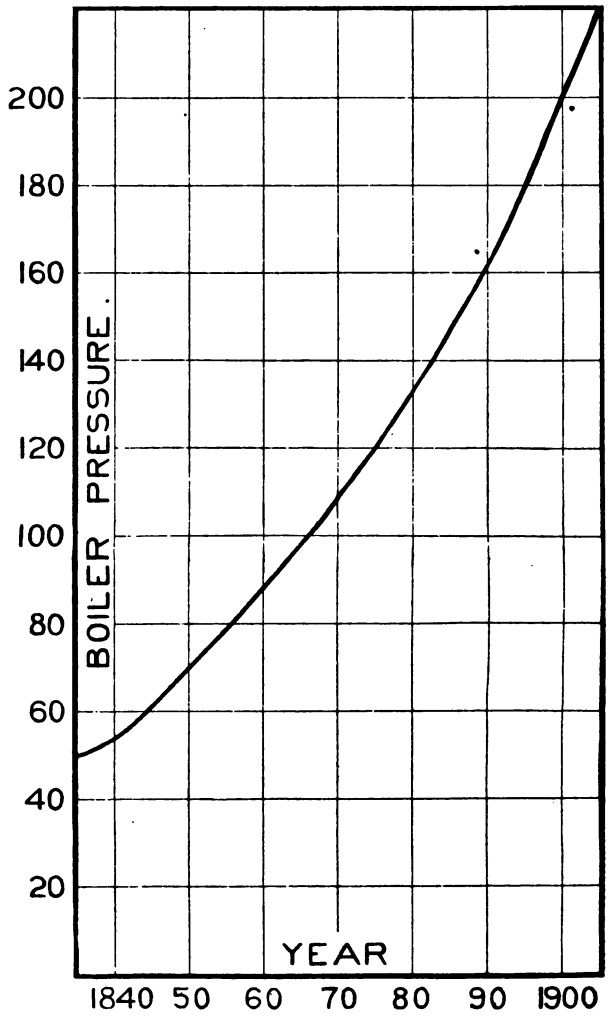

200
180
160
140
120
100
80
60
40
20
BOILER PRESSURE.
YEAR
1840 50 60 70 80 90 1900

FIGURE 1

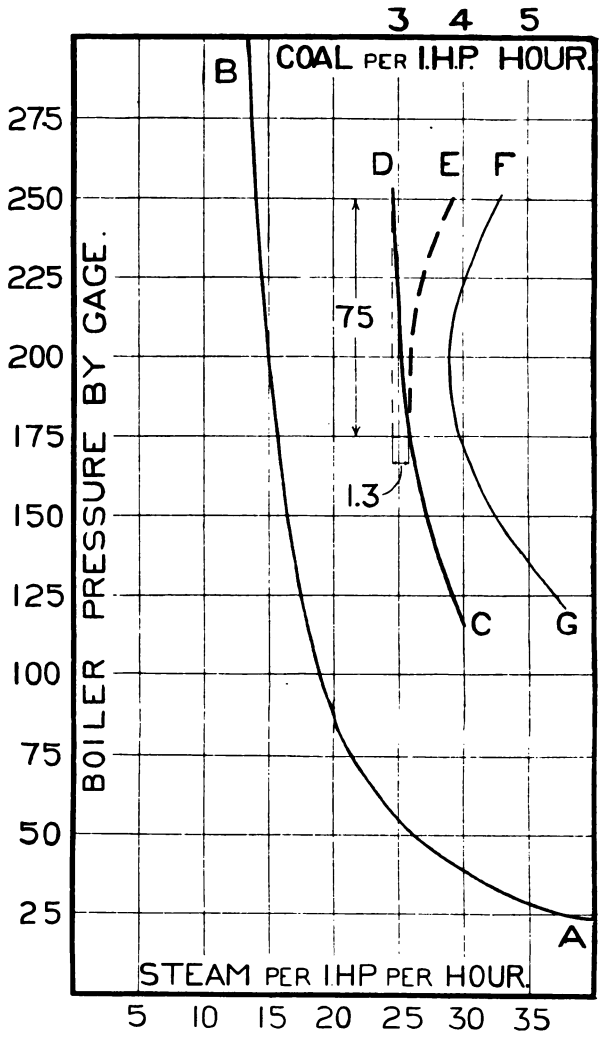

3 4 5
COAL PER I.H.P. HOUR.
B
D E F
275
250
225
200
175
150
125
100
75
50
25
75
1.3
C
G
A
BOILER PRESSURE BY GAGE.
STEAM PER I.HP PER HOUR.
5 10 15 20 25 30 35

FIGURE 2

beginning with a pressure of 25 pounds the steam consumption per h.-p. hour of this perfect engine is 40 pounds, and that the steam consumption diminishes rapidly as the pressure is increased until the pressure becomes considerable. For the higher range of pressure, the increase in performance is very slight. For example, if you will scan the upper portion of that curve you will note that from 175 pounds to 275 pounds the inclination of the line is very slight. The performance at the higher pressure is but slightly better than that at 175 pounds. From this statement it appears that from theoretical considerations alone we should not expect any large improvement in the efficiency of the locomotive by merely increasing pressure.

Turning now to an experimental side of the question and considering what the actual performance of a locomotive may be when served with pressures of different values, I present to you the line C D, which fairly represents a series of more than seventy tests, all under pressures ranging from 120 to 250 pounds per square inch, and which have been conducted under the patronage of the Carnegie Institution. This curve C D fairly represents these seventy tests, showing the steam consumption per h.-p. hour for the several pressures given. I call your attention also to the form of this curve. Its upper portion you will see is almost vertical. The change in performance when the pressure is increased from 175 pounds to 250 pounds amounts only to 1.3 pounds of steam per h.-p. hour. Moreover, I would add that these curves are plotted as shown in terms of steam per h.-p. hour, inasmuch as, at the higher pressures, a pound of steam represents more heat than at the lower pressure. If the plottings were made upon a heat basis alone, these lines would be even more nearly vertical than they are shown.

The results which are represented by line C D are obtained in return for great vigilance in the maintenance of boiler and engine. Small leaks occur, especially at the higher pressures, which, while they may attract but little attention, become the source of serious losses. These leaks and the effect which they have upon cylinder performance are more difficult to deal with as the range of pressure increases, so that if we take an actual engine working under conditions of service, the actual performance, as measured by steam per h.-p. hour, is likely to take

some other curve, not the curve C D, but some curve, which may be C E. That is, the expected gain when the pressure is increased actually becomes a loss through incidental causes, chiefly through leaks.

Of course, the problem of coal consumption per h.-p. hour is after all that which we are after. I can not present to you any curve of coal consumption which will be as representative as that which I have given for steam consumption, since the data covering coal performance is not yet in hand; but I do present to you a curve which I have lettered F G which represents one series of tests. All the tests which were made were made with a given cut-off, about one-fourth stroke — perhaps 15 or 18 tests altogether — and you will note that on the basis of coal consumption as determined from these few tests, we have the minimum consumption at a pressure not greater, at any rate, than 200 pounds, and when the pressure is increased above that limit, the coal consumption increases. I should say that the values to which the curve F G refers are given at the top of the diagram and not at the bottom.

This presents to you in rather brief form the performance of a single actual engine as regards cylinder performance and coal consumption. I must call your attention to the fact that this is not a fair and full statement of all of the problem involved, because of the fact that the tests here were run at comparatively low pressures, with a boiler which was designed for 250 pounds pressure — that is, it was lower than a high-pressure boiler.

Suppose, now, instead of proceeding as has been done with these experiments, there had been a new boiler available for each of these different pressures, which boilers would be constant in weight, but those which were designed for low pressures would be made enough larger in their heating surface to maintain their weight; that is, suppose in this record we had taken advantage of the opportunities which the selection of lower pressure would give for increasing the size of the boiler. It would then appear that all of these lines would show a lower steam consumption and a lower coal consumption, as we go downward. That is, the upper end of these lines would at once move to the right, showing that the point of minimum consump-

tion would be lower than the points which are shown by them, and as a problem in design of course it is that view which must in the end prevail.

Summarizing the statements already made and adding others thereto, the following will be found to be true:

1. Very high steam pressures are not essential to the development of high power.

2. The advantages to be obtained from an increase of pressure above any given limit are only such as may be derived from an improvement in cylinder performance and from a reduction in the dimensions of cylinders. For all increments of pressure above 150 pounds, the possible improvement in cylinder performance will be small; above 185 pounds it is practically negligible. As to cylinders, it may be noted that conditions external to the locomotive may sometimes require the use of abnormally small cylinders, but such conditions will not often be a controlling factor. It is true also that small cylinders permit the use of lighter pistons, and hence they tend to simplify the problem of counterbalancing.

3. The disadvantages to be met when the pressure is increased above any given limit are as follows:

(a) An increased weight of boiler for a given amount of heating surface, or when the designer is required to observe weight limits, less heating surface than might otherwise be used and hence a boiler of lower efficiency.

(b) Where feed-water is of poor quality it increases the difficulty attending the maintenance in working condition of injectors and boiler checks.

(c) It complicates the problem of keeping boilers tight, and in general adds enormously to the cost of boiler maintenance.

(d) It increases incidental losses, especially those occurring in the form of leaks of steam or water from boiler and engines.

From these considerations it appears that a general solution of the problem of determining what is the most economical pressure for a locomotive involves three sets of facts: (1) Those defining cylinder and boiler performance; (2) those dealing with the weight of boilers designed for different pressures and

different capacities: (3) the degree of perfection with which the locomotives are to be maintained in service.

An abundance of data covering the first two of these points is now in hand, while the third probably can never be absolutely defined.

I may say that during the summer it is expected that an analysis based upon this data to which I have referred will be made, and I am hoping that by fall I shall be able to add to this discussion something that will be more conclusive than that which I give now.

Meantime, I can only say, in response to the specific question which has been assigned me, that my investigations justify the assertion that a pressure of 185 pounds will give better results in a simple locomotive, using saturated steam, than would be obtained from a pressure of 200 pounds.

THE PRESIDENT: The subject is now open for general discussion.

MR. A. E. MITCHELL: I move we extend to Professor Goss a vote of thanks for the able discussion which he has given us on the subject assigned to him. (Motion carried.)

THE PRESIDENT: Unless there is some discussion on this subject we will take up the next topic of discussion.

MR. G. W. WILDIN (Erie): I move that the subject be closed. (Carried.)

THE PRESIDENT: The next business in order is topical discussion No. 2 — "The Necessity of Proportioning Brake Pressure to Wheel Loads," to be opened by Mr. George L. Fowler.

MR. GEORGE L. FOWLER: Inasmuch as this topic was practically discussed by the Car Builders' Association, and a resolution adopted by that Association in regard to the matter, I would move that the subject be dropped, although I am prepared to open it.

MR. G. W. WILDIN (Erie): I will second the motion, with the understanding that we go on record in this Association the same as we did in the other.

THE PRESIDENT: What was the recommendation?

MR. G. L. FOWLER: The recommendation made by Mr. West in opening the discussion before the Master Car Builders' Association was that at the present time it was not necessary to make the brake-shoe pressure proportional to the load on the wheels. I disagree with him.

MR. J. F. DEEMS: Was this motion seconded and passed?

THE PRESIDENT: No; the seconding was conditional.

MR. J. F. DEEMS: If it was not conditional, I want to make it so. I think we should have the benefit of Mr. Fowler's paper and not agree to let it pass.

THE PRESIDENT: I think we had better have the discussion by Mr. Fowler.

THE NECESSITY OF PROPORTIONING BRAKE PRESSURE TO WHEEL LOADS.

MR. GEO. L. FOWLER: I have no paper to present. The subject was assigned to me to open the discussion. I have simply a suggestion to make in regard to the matter, and that is it seems to me, under the present conditions of high capacity cars, that something more than the ordinary brake-shoe pressure proportional to the empty cars should be put upon them. Take a car of 110,000 pounds capacity, load weighing 35,000 pounds, for example; that gives about 145,000 pounds on the wheels of the loaded car. The proportion of brake pressure is 70 per cent of the empty car, which gives practically only 17 per cent braking pressure for the loaded car. As braking pressures operate the same as accelerating pressure, except in the opposite direction, of course the length of run after the brakes are applied would necessarily be four times as far with the loaded train as with the empty train. I can readily understand that to apply a varying brake-shoe pressure to loaded and empty cars in ordinary merchandise service would be an impracticable arrangement under present conditions. Cars are loaded to such varying weights, they run over such varying routes, and are subject to such abnormal conditions, you might say, in reference to each other, that to make a design that would be automatic or non-automatic would hardly be practicable, although it has been attempted a

great many times and the patent office is full of records of devices of this sort. But for coal trains, or ore trains, and possibly cattle trains, running in regular service, forward and backward like a shuttlecock, it seems to me for such service as that a design which can be put on a car that could cut in or cut out, according as the car is loaded or empty, would be an exceedingly valuable device. It would be more valuable if the automatic arrangement could be made to operate in only one direction — that is, to have it cut out; for example: a train runs into the mines, loads with coal and starts to the seaboard. Coming down, as most of these trains run down grade, if such a device for adding the brake pressure is cut in, the engineer has the full advantage of the load — of its extra brake pressure, whereas, on his return, if it cuts out automatically, he has simply the brake-shoe pressure applicable to the empty cars. In actual practice such work usually means that where the device is not automatic they are not really cut out, but the engineers become so used to it that they use a lower train-pipe reduction on the empty than on the loaded cars, so that the brake-shoe pressures are proportional in accordance with that, and investigation will show that the actual amount of air consumed on a train that is running with a device of that sort will be less than it will be where the ordinary brake is used, using 70 per cent of the brake-shoe pressure on the empty cars. While the Master Car Builders' Association decided positively, possibly with the intention of only referring to ordinary merchandise cars, that it was not yet desirable to make a variation in brake-shoe pressure upon their wheels, yet it does seem to me that where a difference of four times is made in the actual stopping possibilities of a heavily loaded train always going down grade, as such cars usually do, coming out from the mines, that such a device as that and such a possibility of obtaining such results is exceedingly desirable.

THE PRESIDENT: Is there any further discussion on this subject?

MR. J. F. DEEMS: I move that the discussion be closed. (Carried.)

THE PRESIDENT: The next business is topical discussion, "Is it Practical to use the Prosser Tool in Roundhouse **Running**

Repairs," to be opened by Mr. F. R. Cooper. As Mr. Cooper is not present we will lay that discussion over. We will therefore take up the individual paper on "Valve Gears for Locomotives," by Mr. C. J. Mellin. (Mr. Mellin read the paper.)

SPECIAL VALVE GEARS FOR LOCOMOTIVES.

BY MR. C. J. MELLIN.

Pursuant to the request of the Committee on Subjects to present a paper on Special Valve Gears, as the Walschaert, Allfree, Young, etc., I beg to submit the following, based on the understanding that it includes only such gears as are applicable to locomotives.

As several gears in use on locomotives are derivations from others not suitable for locomotives, it may in a few cases be of advantage, however, to go back to the origin from which they are developed, and others referred to as comparisons in being applicable but do not possess sufficient advantages for acquiring any extended adoption.

GOOCH VALVE MOTION.

Among the latter class may be mentioned the Gooch, or stationary link motion, which might be said to be the opposite of Stephenson motion, in that the valve rod or link block is raised and lowered in reversing the engine, instead of the link in the latter. It is operated with two eccentrics set in the same relation to the crank as in Stephenson's gear, and the link is curved to a radius equal to the length of the valve rod or radius bar and turned with its convex side to the axle as shown in Fig. 1. This motion gives a constant lead and has otherwise no advantage over the Stephenson gear, except, possibly, that the link block and the radius bar are lighter to lift in reversing than the link; but it presents an objectionable feature in that the sweep of the radius bar in its raising and lowering is obstructed by the front driving axle when the main connection is made to the second or third pair of wheels, and is probably the principal reason why the Gooch gear has been in little use and is now practically abandoned altogether in locomotive service.

ALLAN VALVE MOTION.

The Allan motion (Fig. 2) may be said to be a combination of the Stephenson and Gooch gear, as the link and valve rod are both moved in opposite directions, so that the angularities and distances in either direction are reduced to one-half of those in either of the other motions under comparison with an increase of lead amounting to about one-half of that obtained by the Stephenson gear in linking up the engine. For this reason the Allan gear has been the favorite valve motion in continental Europe for a generation or more.

With properly selected lengths of lifting arms of the reverse shaft the link is made straight instead of curved as in the previous cases, which, in manufacturing in former days, was of no little importance in its favor. We see also from Fig. 2 that the lifting arms are placed on opposite sides of the reversing shafts, necessitated by the required opposite vertical motion

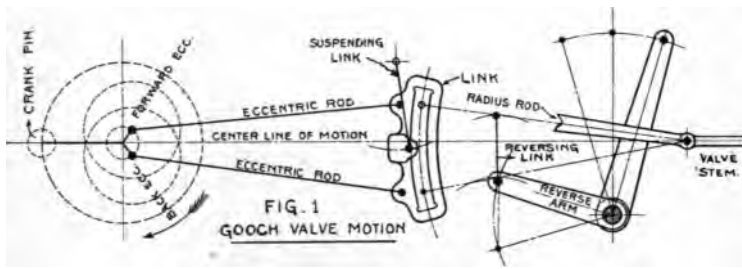


FIG. 1
GOOCH VALVE MOTION

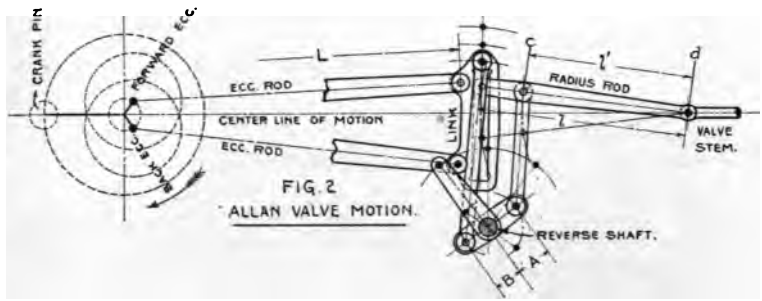


FIG. 2
ALLAN VALVE MOTION.

of the link and valve rod in changing the cut-off or reversing the engine and thereby practically balancing each other and holding the reversing shaft in an approximate equilibrium at any position of the reversing lever.

These are all properties of considerable advantage over either the Stephenson or Gooch gears and deserve therefore a closer description.

From Fig. 2 we see that it is operated by two eccentrics and rods connected to the link in the ordinary way, one for the forward and the other for the backward motion of the engine, with open rods as in the case of Stephenson motion both for outside and inside admission valves so that the lead is always increasing in linking up the engine. The reversing shaft can be located above or below the link as is found most convenient without in any perceptible way affecting the distribution of the steam. The proportions of the lengths of the rods and lifting arms are very important in order that there may be a complete compensation for the gain of horizontal length by one rod to the loss by the others in change of angularity of the rods in linking up or down. These proportions can hardly be found

by trial, but must be carefully figured out and are found by the following formula:

$$\frac{A}{B} = \frac{l^1}{L}\left(1 + \sqrt{1 + \frac{L}{l}}\right)$$

L = length of the eccentric rod.
l = length of the radius rod.
l^1 = distance c-d in the figure.
A = length of radius rod lift arm.
B = link lift arm.
$l\text{-}l^1 = A+B$.

Although the Allan motion is the most correct one in existence it has never gotten any foothold in America, probably for the reason that it has to some extent the same objectionable feature as the Gooch in regard to the front driving axle, which, however, is not serious, as the short vertical sweep of the valve rod admits of a bend or a yoke for straddling same. As this motion is located inside the frames and occupies about the same place and is of the same weight as the Stephenson gear, on modern engines it would be heavy and cumbersome to apply, so its introduction at this time is hardly to be looked for. These conditions have also made themselves manifest in Europe, and the Allan gear, in spite of its excellent qualities, is fast disappearing from modern locomotives, being displaced by the more advantageous construction and application of the Walschaert motion, which will be referred to later.

The Stephenson, Gooch and Allan motions can be classified as one system in that they are all based on the two eccentrics set in symmetrical relation to the line of motion, one governing the forward and the other the backward movement of the engine, differing principally only in the matter of lead. In the Gooch gear, with its constant lead, it makes little difference if the rods are crossed or open, but in the Allan and Stephenson it is important that the rods are always open so that there is no reduction of lead in linking up, as crossed rods will reduce the port opening at the earlier cut-off and cause an unfavorable wire-drawing of the steam.

The expression "open rods" has therefore its definition in that it gives an increase of lead and crossed rods a reduced lead in linking up the engine, but it may not be out of place in this connection to also define their relative positions to the crank under the various conditions of direct and indirect motions and outside and inside steam admission valves. Therefore, in a valve gear having direct motion and outside admission valve, the eccentrics at the beginning of the forward stroke will be placed between the link and the center of the axle and the crank will be on the opposite side of the axle. If in this position the upper eccentric be connected to the upper link pin and the lower eccentric to the lower link pin, we will have open rods as shown in Fig. 3 represented with Stephenson link. In a valve gear with indirect motion, the eccentrics will be placed between the link and center of the axle and the crank on its center on the same

side of the axle. If in this position the upper eccentric be connected to the upper link pin and the lower eccentric connected to the lower link pin, we will have open rods as shown in Fig. 4. If in same positions the upper eccentric be connected to the lower link pin and the lower eccentric to the upper link pin we will have crossed rods as per Figs. 5 and 6 respectively. With inside admission valve we will have the crank and eccentric positions shown in Fig. 3 for indirect motion and in Fig. 4 for direct motion, and in both cases we have open rods, and in Fig. 5 indirect and in Fig. 6 direct

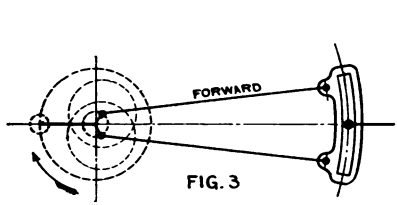


FIG. 3

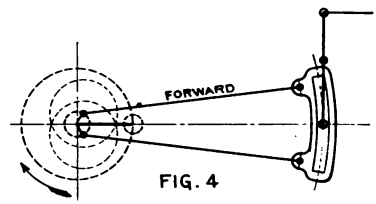


FIG. 4

FIG. 3.— Position of eccentrics of open rods for direct motion with outside admission valve and indirect motion with inside admission valve.

FIG. 4.— Position of eccentrics of open rods for indirect motion with outside admission valve and for direct motion with inside admission valve.

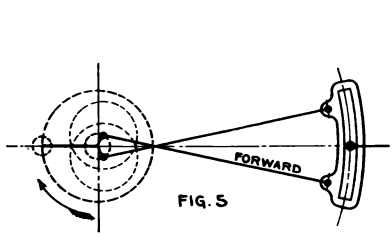


FIG. 5

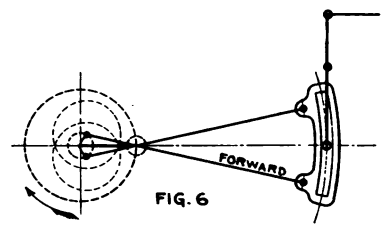


FIG. 6

FIG. 5.— Position of eccentrics of crossed rods for direct motion with outside admission valve and for indirect motion with inside admission valve.

FIG. 6.— Position of eccentrics of crossed rods for indirect motion with outside admission valve and direct motion with inside admission valve.

motion, with cross rods. By this it is seen that the valve events are the same for outside admission and direct motion as they are with inside admission and indirect motion, and vice versa.

HACKWORTH VALVE MOTION.

There are various kinds of valve motions that are driven with a single eccentric, among which the oldest probably is that of John Wesley Hackworth, which was designed sometime between 1840 and 1850, and while this type in its original form (shown in Fig. 7) is not suitable for locomotives, it is referred to as the starting point for a number of modifications, of

which a few will be presented, in the line of its evolution to fairly good valve motions for locomotives under various names of so-called "radial" gears.

The eccentric in this design can be placed either on the same center line as the crank or directly opposite, depending upon whether the valve rod connection is made between the eccentric and the link block or whether the link block is located between the valve rod connection and the eccentric. The link is occasionally made straight for very long valve rods, but is more correctly curved to a radius of the length of the rod and is pivoted on its center while the block slides from one end of the link to the other and back

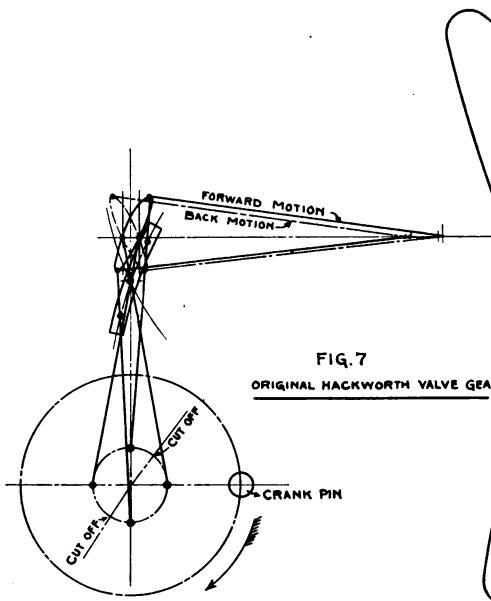


FIG. 7
ORIGINAL HACKWORTH VALVE GEAR.

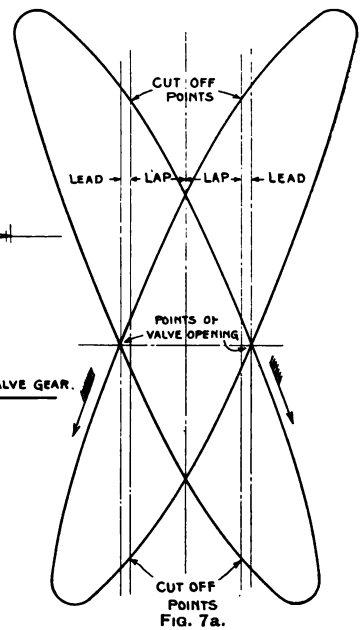


FIG. 7a.

at every revolution of the crank. The link fulcrum is the reversing shaft by which the link is turned to any desirable angle that will give the required throw and cut-off of the valve, and the lap and lead motion is obtained by the lever action of the eccentric arm which, therefore, gives a constant lead, whereas the opening motion of the valve is imparted by the regular inclination of the link, and the combined paths of the valve rod pin are represented in Fig. 7a in enlarged scale.

In 1859 Hackworth introduced a swinging lever instead of the link, which at that time did not seem to be brought into use, as the required length of an arm to carry same was impracticable. Mr. Brown, who has made many valuable improvements in the development of this gear, intro-

duced a counterswinging link by which any radius could be obtained, but the arrangement was rather complicated and has apparently never reached any extended use until again improved upon by Klug, in 1878, and Marshall, in 1880, by practically reinventing the Hackworth construction of 1859, and the gear in that form has since been known mostly as the Marshall gear and has to a great extent been in use on marine engines and auxiliary machinery on board ships.

Another form designed by Hackworth is shown in Fig. 8, where he attaches the eccentric rod or combination lever to a point near the middle

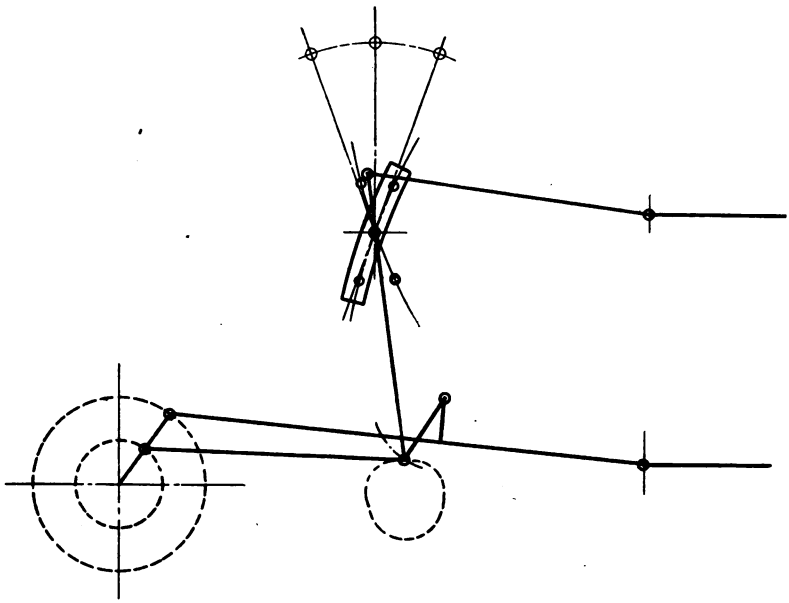


FIG. 8

HACKWORTH VALVE GEAR.

of the connecting rod by means of an intermittent hanger having one end connected to a return crank on the main pin to obtain a shorter longitudinal motion of the combination lever than that of the stroke of the engine; the reversing shaft being located above the center of this connection in the same way as in his previous design above the engine shaft. This was further modified by Brown, in 1878, by introducing a system of levers to reduce the swing of the combination lever, instead of the return crank.

JOY MODIFICATION.

In 1879 Mr. Joy applied this gear with a slight modification to a locomotive engine and it is therefore generally known as Joy's gear. It is

largely used in Russia and to some extent in several other countries without having gained any predominating use over the Allan motion which, as said before, until a few years ago was the general favorite in continental Europe. Fig. 9 shows the Joy gear in a general way, and it is probably the highest development of the Hackworth motion adaptable to locomotives and gives a very good steam distribution when properly fitted up, but the effect on the movement of the valve by the vertical play of the main axle on a rough track is not entirely eliminated.

In this arrangement, as well as in the original, and in fact in all modifications of the Hackworth gear, the link block or combination lever fulcrum can be guided by a curved frame ("link" as it has been called on

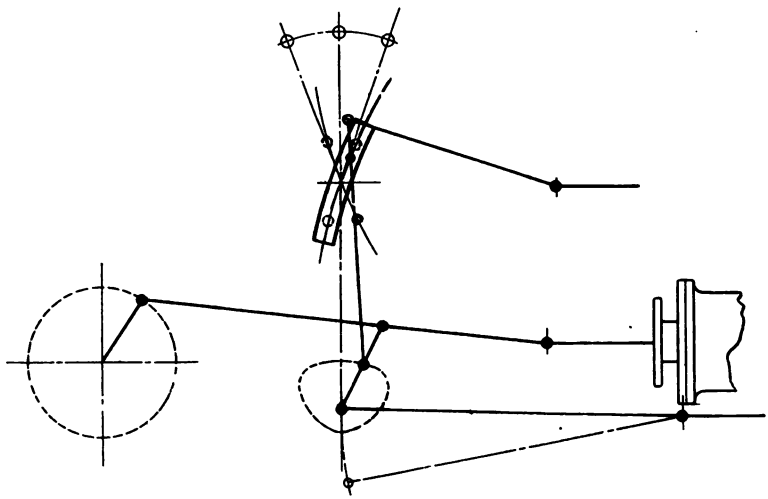


FIG. 9

JOY VALVE GEAR.

account of its similarity to the ordinary reversing links), or by a swinging link and arm of approximately the same length as the radius bar where such a construction is applicable.

No principle of valve motions has been so fascinating and subject to so many varieties of construction as that of Hackworth, and a score or more inventors have, with comparatively small modifications, found them meritorious enough to connect them with their names.

WALSCHAERT VALVE MOTION.

The most suitable form of radial gear for locomotives is unquestionably the one invented by the Belgian engineer, Egide Walschaert, in 1844, and applied to locomotives a few years later, which is shown in Figs. 10, 10a and 11, but it was not properly understood or appreciated during the

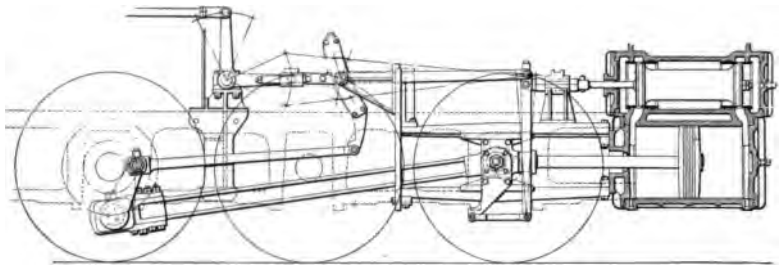


FIG. 10.

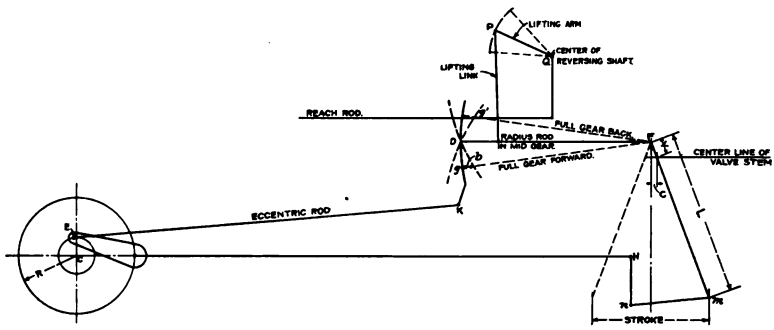


FIG 10a.

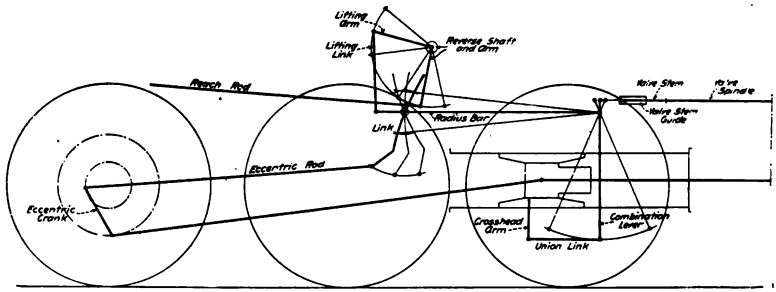


FIG. 11.

first twenty years following its invention, and has ever since then made slow headway until a few years ago, when it took quite a sudden move forward and is at present the dominating valve gear throughout the continent of Europe, and is rapidly gaining ground in this country, where, only within the last two years, it has been applied to engines for regular road service, although it has been in use in sundry cases, principally small engines. This gear may be said to be based on a fundamental principle of its own, but has also been subjected to a few modifications without any special improvement over its original form.

The motion of the valve is derived from two sources, namely, the main crank by connection to the crosshead, and from an eccentric placed approxi-

mately at right angles to the main crank. The crosshead connection imparts the motion of lap and lead at the extremities of the stroke of the piston, at which moment the link is in its central position. Therefore in the mid-gear with the reverse lever in its center notch this will be all the motion imparted to the valve and the radius bar becomes stationary. The link is curved to a radius equal to the length of the radius bar. By moving the reverse lever forward the eccentric motion is brought into combination with the motion from the crosshead, producing a valve opening for the forward motion of the engine, and by moving the reverse lever backward the link block is brought to the opposite side of the link fulcrum, resulting in a valve opening governing the backward motion of the engine, in effect similar to that of the Stephenson motion. The action of this one eccentric is therefore the same as if it was two eccentrics, one for forward and one for backward motion, placed diametrically opposite each other, and the angle of advance in the Stephenson motion is taken care of by the main crank in the crosshead connection. The latter motion being constant, it follows that the lead remains constant at all points of cut-off.

The proportions of the various parts of the Walschaert gear can not be determined experimentally, nor should any change in setting the valves be made unless the effect of the change is known in advance. It is therefore important that the different parts should be made and set correctly from the beginning and there will then be no need for changes when the original dimensions are maintained. The difference in this gear for outside and inside admission valves must be considered in setting the eccentric crank and as the forward motion of the engine should preferably be taken from the lower end of the link when the eccentric crank will *follow* the main crank for *inside* admission valve (see Figs. 10 and 10a), and *lead* the main crank for *outside* admission valve (See Fig. 11).* The connecting point of the radius bar to the combination lever is *above* that of the valve stem connection for *inside* admission and *below* the valve stem connection for *outside* admission valves. (See Figs. 10, 10a and 11). The desired maximum cut-off, lead and valve travel determines the size of the lap, and the lap and lead motion is obtained by the corresponding proportioning of the combination lever and found from the following formula:

R: C = L: V.

R = radius of the main crank.

C = lap and lead (one side).

L = distance between radius bar and crosshead connection (from F to M, Fig. 10a) on the combination lever.

V = distance between the radius bar and valve stem connections.

* With short eccentric rods the distribution will be somewhat improved with inside admission valves when the ahead motion is taken from the upper end of the link and the eccentric crank leads the main crank, but in order to reduce stresses on the link fulcrum the lower end is more generally used, as this refinement will not show any practical difference when the lengths of the radius bar and eccentric rod are not less than three and one-half times their vertical deflections.

The length of the combination lever must be taken to suit the conditions under consideration in each case, so that the angle through which it oscillates will not exceed 60°, but less is preferable. The required horizontal movement or travel of the connecting point F of the radius bar to the combination lever for a given maximum valve travel must now be ascertained and is found by the following formula,* in which R and C are the same as above, namely:

R = radius of main crank.
C = lap and lead.
a = half of the travel of the valve.
b = half the travel of point F.

$$b = \frac{R\sqrt{a^2 - C^2}}{R + C}$$ for outside admission, and

$$b = \frac{R\sqrt{a^2 - C^2}}{R - C}$$ for inside admission valve.

These may also be laid out graphically as per Fig. 12 for outside and Fig. 13* for inside admission valves by drawing a circle with S as a center and a as radius (shown dotted in the figures). Lay out crank radius R to the left from S = Sd and the lap and lead dimension C = Se on same side

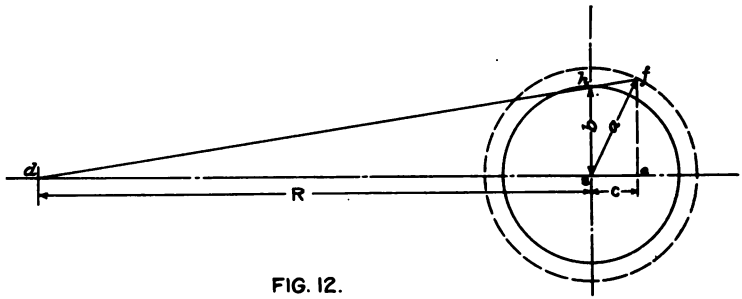


FIG. 12.

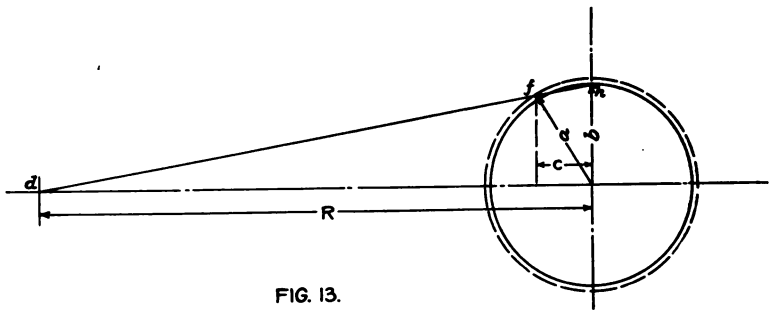


FIG. 13.

* Evolved by the author.

of S for inside admission (Fig. 13), and on opposite side of S for outside admission (Fig. 12). Draw ef and Sh perpendicular to Sd when f becomes the intersecting point between the valve travel circle and the line ef. Draw the line df and where this intersects the line Sh, which point we will call h (found by extending df in Fig. 13); Sh is then the desired dimension b in the formula, or one-half the required movement of point F, the total of which is represented by the full drawn circle in the figures.

This is a most important function of the gear upon which practically all the others depend and is rather complicated to find by plotting. With a correct suspension of the link block it will have the same horizontal movement as the point F, and by limiting the angle of the swing of the link to 45° as a maximum we get the rise or depression of the link block on either side of the link fulcrum the distance $Og = \frac{b^*}{\text{tan. } d}$, (Fig. 10a) where O is the link fulcrum, d = one-half of the swing of the link in degrees, and b = half the travel of point F in the previous formula.

The vertical location of the link fulcrum O should be, when practicable, on a line drawn through point F parallel with the valve stem, and the eccentric rod connecting pin K to the link should be as nearly as practicable on the same level as the main axle in order to minimize the effect of the vertical play of the axle on the valve events, but on large engines it may be found necessary to lower fulcrum O and raise connection K to avoid excessive throw of the eccentric crank.

In locating the longitudinal position of the link fulcrum consideration must be given to the lengths of the eccentric and radius bars so that both may be of approximately the same length. When these lengths fall below three and one-half times the total vertical sweep of the link block the radius bar should be favored in preference to the eccentric rod. The exact position of the eccentric crank must be plotted as well as the longitudinal location of point K. The former must bear such relation to the main crank that it brings the link in its middle position when the main crank is on either of its dead centers and the connecting point K must be so located that it swings the link in the required angle *d* on either side of the middle position of the link; that is, in other words, the point K should be so located on the curve it must follow with fulcrum O as a center that its deviation from the tangent of the eccentric rod to this curve is such that it as near as practicable compensates for the irregularities brought about by the angularities of the main and eccentric rods which in ordinary cases brings it from 2 inches to 5 inches in the rear of the tangent to the link drawn through the fulcrum O.

The locus of the suspension point of the radius bar lifting link must also be plotted so that the link block is at the same point of the link in its extreme positions at all cut-offs. This locus is a curve with its center

*As no suspension gives a perfectly equal drop of the block in both link positions this formula is only approximate.

in the vicinity of the point F when in its mid-gear position. It would be impracticable, however, to have a lift arm of this length, and a curve of smaller radius must be substituted and so applied that it intersects with the former curve at points giving the least possible distortion to the motion favoring the position of the link block in which it is mostly used in service.

The sliding lifter shown in Fig. 10 meets these conditions better than any other method of suspension, but, due to wheel arrangements of various designs of engines, this is not always applicable but must be substituted by swinging lifters as per Figs. 10a and 11, which, when properly plotted, gives for all practical purposes equally good results.

The vertical height of lower connection *m* of the combination lever in relation to the crosshead connection has a slight influence on the port open-

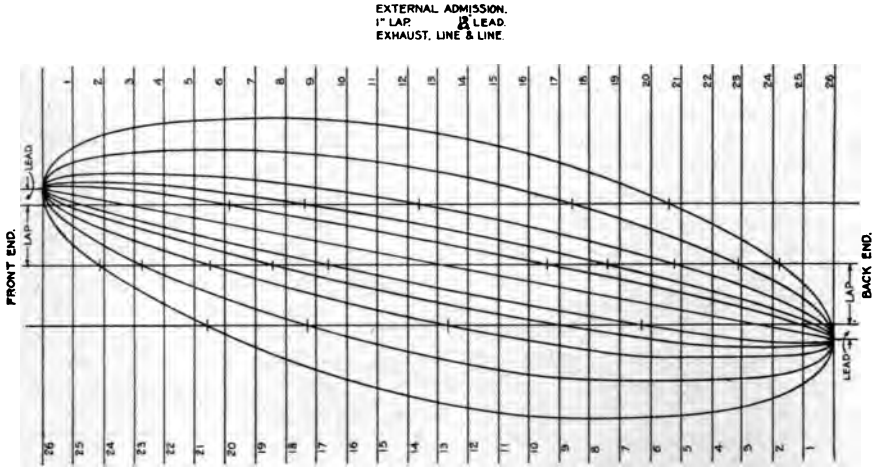


FIG. 14.

ing and should, therefore, in the center position of the lever, be about in the same level as the crosshead connecting point *n* (see Fig. 11).

In Fig. 14 is the motion of the valve graphically represented by the Long diagram at different cut-offs where the horizontal lines represent the port opening edges in the cylinder face and the curves of the steam inlet edges of the valve, showing the opening and cut-off points where the latter intersect the former and the port openings at the various points of the stroke are measured by the height of these curves over and under the opening edges of the ports at both ends of the valve respectively.

It will be noticed that these ellipses are slightly flattened on one side, which is caused by the slower lineal motion imparted to the valve relative to the angular motion when the eccentric passes its back center compared with that of the front center due to the angularity of the eccentric rod and is more marked the shorter the rod. Fully symmetrical ellipses are

not obtainable as this would require the eccentric and main rods to be of infinite length, but this angularity however is of but little detriment to the distribution of the steam as long as the relations between the lengths of the eccentric rod and the throw of the eccentric is not less than the given limitations, and is present in all kinds of continuous valve motions derived from uniformly rotating cranks or eccentrics.

GENERAL NOTES FOR ADJUSTING WALSCHAERT GEAR.

1. Ascertain by the following method the position of the eccentric crank: Mark the position of the link relative to its middle position on both of the dead centers of the main crank. If the position of the link is the same in both cases the eccentric crank position is correct, if not the eccentric crank should be shifted until this occurs or as near so as possible.

2. After the eccentric crank has been correctly set the eccentric rod should be lengthened or shortened as may be required to bring the link in its middle position when the main crank is on either of its dead centers, so that the link block can be moved from its extreme forward to its extreme backward position without imparting any motion to the valve. It may be noted that the link position may be observed by the usual tram marks on the valve stem, or direct by marks on the link pin as may be found most convenient with the link block in full gear, preferably ahead.

3. The difference between the two positions of the valve on the forward and back centers of the engine is the lap and lead doubled; it is the same in any position of the link block and can not be changed without changing the leverage relations of the combination lever.

4. The tram marks of the opening moments at both ends of the valve should be marked on the valve stem and the latter lengthened or shortened until equal leads at both ends are obtained.

5. Within certain limits this lengthening or shortening may be made on the radius bar, if it should prove more convenient, but it is desirable that the length of this bar should be so nearly equal to the radius of the link that no apparent change in the lead should occur in moving the link block as stated in note No. 2.

6. The lead may be increased by reducing the lap and the cut-off points will then be slightly advanced. Increasing the lap produces the opposite effect on the cut-off and reduces the lead the same amount. With good judgment these quantities may be varied to offset the irregularities inherent in transforming rotary into lineal motions.

7. The valve events are to a great extent dependent on the location of the suspension point of lifter of the rear end of the radius bar, when swinging lifter is used, which requires that this point should be properly laid out by careful plotting, or, if convenient, it is preferably determined by a model, as irregularities due to incorrect locus of this point can not be corrected by the other parts of the gear without more or less distortion

of same. When this point is so fixed that a change of same is impracticable it may be better however to modify other elements if thereby the motion in general can be improved.

The chief point of difference between the Walschaert and Stephenson gear when both are in proper conditions is, as previously stated, that the former gives to the valve a constant lead at all cut-offs, whereas the latter produces an increase of lead by linking up the engine and becomes excessive at short cut-offs. This very point has been the subject for much controversy and has probably done more than anything else to retard the progress of the use of Walschaert gear; as it has been argued that in full gear, when the speed generally is slow only small lead is needed, but at higher speed more lead is required, which is accomplished by the Stephenson motion, though this admittedly becomes excessive at early cut-offs, causing considerable compression and preadmission detrimental both to maintenance and to smooth running, and, in fact, to some degree counteracts the work done by the steam on the driving side of the piston, which thereby also affects the speed of the engine.

It was gradually discovered that the required lead for short cut-off and high speed was of no practical detriment to the working of the engine in full gear as the preadmission at that point is disappearingly small. The proper amount of lead however is dependent somewhat on the service, and the port opening becomes larger with a larger lead, or, in other words, when all other conditions are equal in a Stephenson or Walschaert gear the openings differ by the same amount as the lead, so that 1-16 inch more lead gives 1-16 inch wider port opening; but it is hardly advisable to make this over ¼ inch or 5-16 inch as a maximum, as the advantage of any additional port opening by means of a larger lead is more than offset by the increase in compression and preadmission the larger lead would bring about at early cut-offs, and would do no good in the later cut-offs even if it does not do any harm.

There is no fundamental reason that the Walschaert gear should produce any economy in steam consumption over the Stephenson motion when both are in the best conditions, but an advantage in this respect comes to the former by the fact that it remains in its good condition if once made so, from one shopping to another, and is therefore on an average more economical both in steam consumption and maintenance of the gear than the latter. The accessibility for attention is a great point of undisputed advantage of the Walschaert gear which is also highly appreciated by the enginemen and attendants.

It will be borne out in the course of time that the bracing between the frames permitted by the Walschaert gear will bring about a considerable reduction in the maintenance expenses by the less wear and tear this additional rigidity will impart to the entire engine.

HELMHOLTZ MODIFICATION.

Among the various modifications of the Walschaert gear the one made by Helmholtz is probably of some advantage. This modification consists in making the link straight and the radius bar is connected to the lifting link instead of the link block. The curving of the link is compensated for by the reversing shaft or lifting arm fulcrum being located in a given position above the link so that the locus of the suspension point of the lifting link forms an arc of a circle with its chord perpendicular to the center line of the radius bar in its center position. The radius of this arc bears the same relation to the length of the radius bar as the distance of the radius bar connection above the link block bears to the length of the lifting link, which results in that this connection is moving in an arc with a radius of the length of the radius bar and the same motion of the valve is obtained as in the direct Walschaert gear.

Two advantages may be claimed for this modification, of which one is the straight link being simpler to make than the curved one, and the other is that on large piston valve engines with inside admission the link fulcrum can be lowered by the amount the radius bar connection falls over the link block, whereby the eccentric rod connection can be brought closer to the center line of the axle with less length of link and eccentric throw. It has, however, the disadvantage that there is little choice in the location of the reversing shaft or lifting arm fulcrum, a proper position for which is hardly obtainable on all types of engines and admits of no other method of lifting the radius bar in linking up or reversing the engine.

ALLFREE-HUBBELL GEAR ATTACHMENT.

The Allfree auxiliary motion is an attachment to the ordinary Stephenson motion by which the valve is given a symmetrical, irregular motion, causing it to open and close quickly. The effect of this movement is the same as is accomplished with a valve having an exceptionally long valve travel, but by this arrangement is obtained a delay of the final exhaust and compression, thereby prolonging the expansion, reducing the compression and preadmission.

The general construction of the Allfree-Hubbell geared system is shown in Fig. 15 and consists in substituting for the knuckle pin joining the valve stem to the rocker arm a small crank shaft, to which crank the valve stem is connected and the shaft left free to revolve in the rocker-arm bearing. To this shaft a pinion is keyed engaging a toothed wheel sector oscillating on the rocker shaft by means of a lever connection from the crosshead. This gives a composite motion to the valve, namely one direct from the eccentrics and one from the crosshead transmitted by the rotation of the crank on the knuckle pin shaft in such a way that the two motions coincide at the opening and closing moments, but are in opposition at the extreme travel of the valve, when the latter is nearly at a standstill, while the main crank passes through a comparatively large angle with a uniformly open port, and the closing of the valve is rapidly

accelerated in the same manner as the opening, causing a quick and sharp cut-off. Fig. 16 gives an approximate illustration of the motion of the valve relative to the ordinary circular motions represented by a Zeuner diagram. The exhaust and compression are similarly affected by this alternating, accelerating and retarding motion of the valve, delaying the exhaust and compression even at early cut-offs.

The advantages, as already stated, are in securing a prolonged expansion and a reduced compression and preadmission. It presents some complication in its attachment, especially on certain types of engines when the driving wheels are straddled by the guide yoke and thereby limiting the space required for the rocker, for the rocker arms and bearings.

YOUNG VALVE ARRANGEMENT.

This gear consists chiefly in the application of the Corliss valves to the locomotive engine with one valve both for the steam inlet and the exhaust

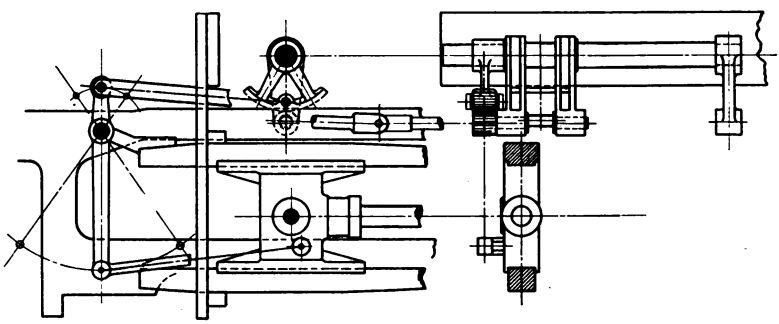


FIG. 15
ALLFREE VALVE GEAR.

at each end of the cylinder. Each valve is provided with double admission and exhaust ports as shown by Fig. 18. The steam ports are practically opposite each other, and the relation of the edges of the ports in the valve to these ports corresponds to that of the valve edges to the steam ports of the ordinary slide valve, forming the steam laps, lead and exhaust laps or clearance as the case may be. The exhaust cavity is a passage diametrically through the valve of sufficient width on one side to combine both steam ports with the main exhaust port simultaneously during the exhaust period. At right angles to the exhaust passage is a similar but somewhat larger cavity which corresponds to the steam chest with transverse passages through the valve body alternating with the exhaust passages, and the lap and exhaust edges are surrounded by carefully fitted slats, both on sides and ends to prevent leakage.

The motion is transmitted through a pivoted wrist plate to the valve from an ordinary Stephenson valve motion as indicated in Fig. 17. By

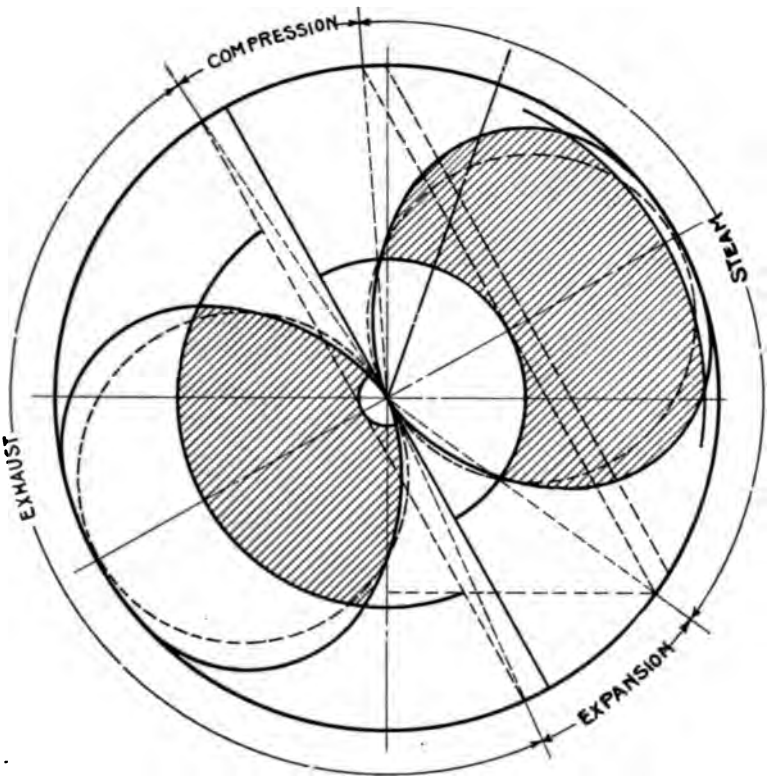


FIG. 16.

ZEUNER DIAGRAM APPLIED TO
ALLFREE VALVE MOTION ATTACHMENT.

means of pivoting the wrist plate on the arm of a bell crank whose other arm is connected with a union rod to a short arm on the reverse shaft, the wrist plate is raised and lowered by the motion of the reverse lever producing a moderate increase in lead, an earlier exhaust and later compression than the direct Stephenson motion produces in linking up the engine.

The main advantage of this valve is the quicker admission, closing and exhaust it accomplishes due to the double port openings, and the small resistance it offers to the valve motion, as compared with the slide

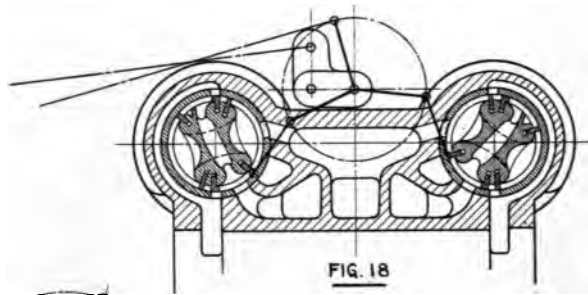


FIG. 18
SECTION THROUGH VALVES & CYLINDER

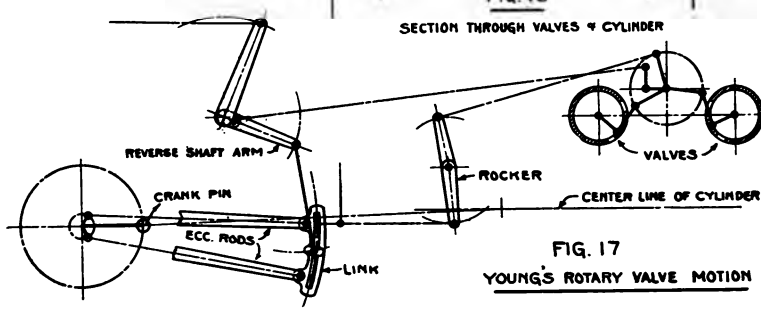


FIG. 17
YOUNG'S ROTARY VALVE MOTION

valve, in being completely balanced. In common with the Allfree gear it gives a higher average pressure at high speeds than the ordinary valve and in a general way the illustration showing port openings in Fig. 16 is applicable also to this valve and gear. This gear, as well as in the previous case, involves additional complications over the ordinary gear, requiring special skill, both in its manufacture and adjustment, which to some extent counterbalances the above named advantages.

There are a few more modifications of various kinds which have not reached any adoption beyond the experimental stage before they were dropped out of existence and they are not of sufficient importance to be taken into consideration in this paper, in which only the most suitable gears for locomotives have been selected, and it is hoped that the few points referred to will furnish material for a discussion of fuller description of results in service from which valuable conclusions may be drawn.

[Applause.]

THE PRESIDENT: You have heard the paper presented by Mr. Mellin. What is your pleasure?

MR. ANGUS SINCLAIR: I move that it be received and opened for discussion. (Seconded and carried.)

THE PRESIDENT: Is Mr. Manning here? You have some of these new gears, haven't you?

MR. J. H. MANNING (D. & H. Co.): It is a little early to come to any conclusion as to the relative merits, but I might say for the benefit of the Association that we have three engines practically of the same design mentioned — 131,000-pound drivers; one equipped with the Allfree-Hubbell motion, one with the Young and another with the Richardson port valve. We tested these engines over a seventy-five mile division, but we have only been comparing them a short time and did not get the figures compiled covering the whole distance. However, in order to have something that I thought possibly some of the members would be interested in, had some figures made up on the ruling grade: Results — a 37-foot grade, about seven miles long. The average draw-bar pull on eighteen readings was in the neighborhood of 25,638 and 24,173, the former delivered by the Allfree-Hubbell and the latter the Young; the engine with the Richardson valve about 23,150. So far as the test has gone and the figures compiled it is a little in favor of the Allfree-Hubbell, producing the same power at the end of the draw bar for a little less fuel than either of the other two. This is over seven miles, however. The figures were taken from an average of eighteen and fourteen readings. I look for something better along this line when we get the figures on the whole seventy-five miles. The Young engine was at a little disadvantage in getting a slow start — was back of the point of the hill. The tonnage was in the neighborhood of 1,639 in one case, 1,640 in another and 1,664. The conditions were nearly identical. The days were about the same as to weather, wind, etc., and the engines all averaged 190, 193, 195. Condition of engines was practically the same and indications favored the Allfree-Hubbell, and verifies the statement that the Allfree-Hubbell gear delivers equivalent power at the draw bar with less fuel than the other two engines. I do not like to say

much on this matter for the reason that our figures were gotten up hurriedly and only cover a short period. I do not want to say anything that will not give me a chance to gracefully back up, if necessary, after I get the balance of the data.

MR. D. J. REDDING (P. & L. E.): Will the gentleman who just spoke give us the maximum draw-bar pull on the three different types of engines?

MR. J. H. MANNING (D. & H. Co.): The maximum draw-bar pull on the Allfree-Hubbell engine was 34,600; the maximum on the Young was 32,300; the maximum on the Richardson was 32,000. The averages run 25,638, 24,175 and 23,150.

MR. D. J. REDDING (P. & L. E.): We have six Allfree-Hubbell locomotives in passenger service, and while there have been no thorough tests run out on these engines, they are doing very good work and we are now about ready to test one of them in comparison with a locomotive of similar type having Stephenson link motion. About the only information I have at present consists of the measurements taken in setting the valves on the two locomotives. The figures for the Allfree-Hubbell are: cut-off 6½ inches, expansion 13½ inches, releasing at 20 inches; closure for compression occurring when piston is within 2½ inches of the end of stroke. For the other locomotive the figures are: cut-off 6½ inches, expansion 11 inches, releasing at 17½ and compression beginning at 8½. These locomotives have cylinders 19 by 26 inches, and are now hauling passenger trains formerly hauled by 20 by 26-inch simple locomotives.

MR. W. L. KELLOGG (Pere Marquette): We have had four of the Allfree-Hubbell engines in service on the Pere Marquette, three of them going into service November 1, 1903, and the fourth one in October, 1904. These are all heavy locomotives. Three of the 2-6-0 class and one of the 2-8-0 class.

We have used some of the 2-6-0 in heavy passenger work, and it has made no difference to what class of service these locomotives have been applied, they have always been found fully equal to the occasion.

I think that the author of the paper has overlooked the actual merits of the system of steam distribution which has been

developed by Messrs. Allfree and Hubbell, in that the advantages of the system are not confined to the rapid opening and closing of the valve as he states, but the advantages are summed up, in my opinion, as follows:

First: Either with the geared system which is applied to our four locomotives, or in the later methods employed by Mr. Allfree, the increased expansion is secured because of their ability to delay exhaust port opening at all points of cut-off, and which is necessarily more marked in the working cuts of back of one-half stroke.

Second: In either system developed by Messrs. Allfree and Hubbell the exhaust closure is delayed in even short cuts until the piston has completed about 90 per cent of its stroke, which necessarily decreases greatly the volume of steam and atmosphere confined in the cylinder, and which at the end of the stroke must be compressed into the striking distance and port volume, and which constitute the cylinder clearance.

Third: Because of the delayed exhaust opening and exhaust closure it has been possible for these gentlemen to redesign the locomotive cylinders and to introduce a number of novel features, which materially reduces cylinder condensation and which is one of the heaviest losses known in operating a steam engine.

Fourth: Because of the delayed exhaust closure necessarily less cylinder clearance is required to take care of the compression, for, as you know, the law of compression is just the reverse of the law for expansion, and with the greater volume to be compressed the more clearance is required to take care of the accumulated compression, and I am firmly convinced that the reduction of the negative work of compression and clearance volumes are very important items in the economies shown by the four engines which we have had in service for an average of considerably over two years each.

Before going to the Pere Marquette road I was connected with another line which at that time did all of the locomotive work for the Kansas City, Mexico & Orient Railway, a line which has twelve of the Allfree-Hubbell locomotives, four of which are of the geared system and eight of them with compression con-

trolling system, in which *no* gearing or auxiliary motion whatever is employed.

Because of these experiences with locomotives of the Allfree-Hubbell type since early in October, 1903, up to date, I am prepared to say that I have found these locomotives to be the most economical in fuel, in repairs, and to develop more power for their size of cylinders, gauge pressure and diameter of wheels than any locomotives that have ever come under my observation.

MR. D. J. DURRELL (Penna. Lines West): We have quite a number of heavy consolidation engines with the Walschaert valve gear. I have no data to present as to the efficiency of the engines equipped with that valve gear, but from our experience of the past year we like it and I think our people will go to it even more extensively. We have it on heavy consolidated engines, and also on the Atlantic type engines, and our people operating the engines speak in the highest terms of it. There have been no serious failures and it is being applied to other engines.

WM. FORSYTH *(Railway Age):* As the principal interest in Mellin's paper is in the Walschaert gear, and Mr. West is on the program for a discussion of that gear, I would suggest that he be asked to give us his discussion now instead of on Wednesday, in connection with this paper.

MR. G. W. WEST: That is a mistake, I don't know anything about it.

MR. ANGUS SINCLAIR (*Railway & Locomotive Engineering*): I don't think the paper which Mr. Mellin brought in is much of a subject for discussion, but I think he deserves the thanks of the Association for the way in which he has the different gears described that are liable to have more application in replacing the Stephenson or shifting link than has been hitherto practiced in this country. There has been something strange about these Walschaert valve gears in the United States. Thirty years ago William Mason turned out quite a number of engines with the Walschaert gear. I had the opportunity at that time of being among the roads considerably that had the gear in use and I never heard a good word for it — never, never. Everybody abused it, and now after this great jump of years, they have got

to be so enthusiastic about these valve gears that they do not know how they can hurry each other along to get on the greatest number. I was always surprised that the gear was so much neglected in this country, knowing what was done with it in Europe, especially after they began to have consolidation engines that it was difficult getting beneath to do anything. It is a desirable gear for such engines as that from the fact that it is particularly come-atable. You can see the whole of it. Of course it is a lighter gear. It reduces the wearing parts considerably.

I am surprised, however, when our people are coming in for improved radial gears that they have not paid more attention to the Joy. The most objectionable part about the Stephenson is the eccentric. The Joy gear does away entirely with the eccentric. It is strange to me that the American master mechanics and designers have not applied the Joy gear, because the disposition of steam is precisely the same, as far as I can make out, as with the Walschaert gear. There is the objection made that the gear is thrown out to some extent by the up and down movement of the axle-box. But I don't think with the roads we have now that that is a serious objection. It is used largely in England. Nearly all the engines that go to Japan from British makers have the Joy gear and I think it would be a good thing if our people would pay more attention to it, when they are improving in that line, merely from the fact that they get rid of the eccentric. The other gears have, no doubt, good points, but they need the stretch of time to tell whether they are going to be much used in American practice or not. Ever since the steam engine was introduced — the locomotive engine was introduced — there has been an effort to get steam quickly into the cylinder and get it out quickly. That, of course, is the object of all these improved valve gears. The difficulty has been that you pay too much for the improvement you get in that respect. There is something about a locomotive that is not well recognized, in regard to the exhaust. The locomotive that throws out its exhaust like a shot always uses more fuel than one that lets the exhaust out more slowly. That is, I believe, the difference between the British and the American locomotive in the economy of fuel, and I think that, until that part is recognized — the part relating to the exhaust of

steam — that we will not get down to the most economical method of operating the locomotive.

MR. G. R. HENDERSON: I think the explanation of our beginning to use the Walschaert gear and the reason we think so much more of it now than thirty years ago is simply owing to the fact that, as Mr. Mellin said in his paper, there was no improvement in the steam distribution expected; but on account of the large bearing surfaces and especially with crank axles, the interior of the engine is so much taken up, and the Walschaert gear lends itself to the outside, we are forced into the use of it now.

MR. C. J. MELLIN: I call attention to Figs. 10 and 11. The figures here do not correspond with the statement. That will be corrected in the Proceedings.

THE PRESIDENT: Is there any further discussions? If not, a motion to close the discussion will be in order.

MR. SINCLAIR: I move the discussion be closed.

(Motion put to vote and carried.)

On motion the meeting adjourned until Tuesday morning, June 19, 1906, at 9:30 o'clock.

TUESDAY'S SESSION.

President Ball called the meeting to order at 9:30 A.M.

THE SECRETARY: Mr. President, I have the report of the Auditing Committee:

ATLANTIC CITY, June 18, 1906.

Your committee, appointed to audit the books and vouchers of the Secretary and Treasurer, begs leaves to report that it has examined all the accounts of the Secretary, and they are found correct, which correspond with the report of the Treasurer.

A. M. WAITT,
A. E. MITCHELL,
J. H. SETCHEL.

MR. PETER H. PECK (C. & W. I.): I move the report of the Auditing Committee be adopted. (Carried.)

THE PRESIDENT: Is there any other unfinished business to be brought before the convention?

THE SECRETARY: No unfinished business, Mr. President.

THE PRESIDENT: The first committee report to be presented at the meeting this morning is the one on Locomotive Tests of the Pennsylvania Railroad at the St. Louis Exposition — Mr. Clark is chairman.

REPORT OF COMMITTEE APPOINTED TO CO-OPERATE WITH THE PENNSYLVANIA RAILROAD SYSTEM IN CONDUCTING TESTS OF LOCOMOTIVES AT THE LOUISIANA PURCHASE EXPOSITION.*

To the American Railway Master Mechanics' Association:

1. At the Saratoga meeting (June, 1903) the Association received a communication over the signatures of Mr. J. J. Turner and Mr. Theodore N. Ely, representing the Pennsylvania Railroad System, and Mr. Willard A. Smith, representing the Louisiana Purchase Exposition, setting forth certain plans of the Pennsylvania System with reference to tests of locomotives at St. Louis, and requesting that a committee of the

* In formulating its report, the committee of this Association has worked in conjunction with a similar committee of the American Society of Mechanical Engineers, the effort being to secure a document which would serve both organizations as a joint report. As a consequence of this arrangement, a report similar in all essential respects with this will be presented by the committees of the American Society of Mechanical Engineers to the Chattanooga meeting of the society, which is to be held in May.

Association be appointed to coöperate with the officials of the railroad system in the advancement of this work. In response thereto a resolution was offered and adopted by the Association, commending the purposes of the Pennsylvania System and authorizing the President of the Association to appoint three members to constitute such a committee. The President subsequently named the undersigned to constitute this committee.

Your committee thus appointed would now report that it has performed the functions for which it was appointed, and presents herewith a statement covering the part which it has taken. It presents also a brief summary of the results which have been obtained from the tests.

2. THE PENNSYLVANIA ORGANIZATION.— The responsibility for the tests at St. Louis rested with the following officials of the Pennsylvania System:

J. J. Turner, Third Vice-President, Pennsylvania Lines West of Pittsburgh.

Theodore N. Ely, Chief of Motive Power, Pennsylvania Railroad System.

F. D. Cassanave, Special Agent, Pennsylvania Railroad System.

E. D. Nelson, Engineer of Tests, Pennsylvania Railroad System.

Coöperating with these were the heads of certain scientific and technical departments of the Railroad System, and especially Mr. A. W. Gibbs, General Superintendent Motive Power, and Mr. A. S. Vogt, Mechanical Engineer. The actual work at the plant was conducted by Mr. G. H. Wall, Director of Tests at St. Louis, assisted by an efficient staff of assistants, observers, computers and enginemen.

The part taken by the Pennsylvania System in proposing tests, in perfecting an organization for carrying them out, and in its execution of the various phases of the work, has been one of unusual significance.

It has brought into existence an entirely new testing plant designed for mounting either freight or passenger locomotives, and capable of absorbing for an indefinite period the maximum power of a modern locomotive when running at any desired rate of speed.

It has caused to be designed and constructed a dynamometer capable of registering the tractive power of the heaviest locomotive, and at the same time so sensitive as to indicate the slightest variation in the force it may exert.

It has purchased and standardized instruments and apparatus for use in securing all data which have been deemed to be of scientific interest.

It has organized a complete corps of observers, engineers and computers to carry out the tests, and to record, tabulate and analyze the results.

It has invited and secured the coöperation of scientific and technical men of this and other countries to assist in placing the tests upon the highest scientific plane possible in such work.

It has overcome difficulties, in many cases perplexing and serious, inci-

dent to the carrying out of such work as a part of a great International Exposition.

It has, as a result of its effort, defined the action of eight different typical locomotives, as regards the performance of the boiler, the engine and of the locomotive as a whole, under many different conditions of operation, making of record a mass of information concerning the economic performance of the modern locomotive of great immediate value, and supplying a basis of comparison which will prove useful for many years to come.

It has met the expense of equipping and operating the plant with an unstinted hand, always holding considerations of cost subordinate to the definite object of making the tests as complete and valuable as possible, notwithstanding the fact that the amounts involved have been far greater than have ever been appropriated to any similar undertaking.

It has carried out a broad plan of publication which has resulted in making data derived from tests, and all conclusions based thereon, together with a description of methods and means employed, all in great detail, accessible to the railroad officials and locomotive designers throughout the world.

3. THE LOUISIANA PURCHASE EXPOSITION was represented in the work by the Hon. Willard A. Smith, Chief of the Department of Transportation Exhibits.

4. THE ADVISORY COMMITTEE.— At the time the invitation to coöperate was received by the American Railway Master Mechanics' Association, a similar communication was sent to the American Society of Mechanical Engineers, asking that organization to appoint a committee of three which would serve with a similar committee appointed by this society. Individual invitations were extended, also, to certain distinguished engineers. The full membership of the Advisory Committee is as follows:

Representing the American Railway Master Mechanics' Association:

F. H. Clark, General Superintendent of Motive Power, Chicago, Burlington & Quincy Railroad.

*C. H. Quereau, Superintendent of Shops, New York Central & Hudson River Railroad.

H. H. Vaughan (Secretary), Superintendent of Motive Power, Canadian Pacific Railway.

Representing the American Society of Mechanical Engineers:

W. F. M. Goss (Chairman), Dean of the Schools of Engineering, Purdue University.

Edwin M. Herr, General Manager, Westinghouse Air Brake Company.

J. E. Sague, First Vice-President, American Locomotive Company.

* During Mr. Quereau's absence from duty in the months of August, September, October and November, Mr. F. M. Whyte, Mechanical Engineer, N. Y. C. & H. R. R. R., was appointed by the Executive Committee of the American Railway Master Mechanics' Association to serve on the Advisory Committee.

Affiliated members:

John A. F. Aspinall, General Manager, Lancaster & Yorkshire Railway, England.

Karl Steinbiss, Director, Royal Prussian Railway, Altona, Germany.

H. V. Wille, Assistant Superintendent, Baldwin Locomotive Works.

Throughout the progress of the work the committee served as an expert board of advisers. It assisted in formulating plans, it approved methods and reviewed results. Individual members of the committees, also, had an active part in giving shape to many matters of detail. The members have observed with unusual fidelity the appointments for the eight formal meetings of the committee which have been as follows:

1.— 1903, June 25. Grand Union hotel, Saratoga, N. Y.

2.— 1903, October 26. Union Station, Pittsburgh, Pa.

3.— 1904, January 28. Union Station, Pittsburgh, Pa.

4.— 1904, May 11. Transportation building, St. Louis Fair.

5.— 1904, July 26. Transportation building, St. Louis Fair.

6.— 1904, November 10. Transportation building, St. Louis Fair.

7.— 1905, May 1. Broad Street Station, Philadelphia, Pa.

8.— 1905, June 12. Broad Street Station, Philadelphia, Pa.

5. THE RESULTS of the tests are well set forth in a formal publication of the Pennsylvania Railway System entitled "Locomotive Tests and Exhibits, Pennsylvania Railway System, Louisiana Purchase Exposition,"* a volume of 727 pages containing approximately nine hundred illustrations.

In attempting to discuss results, your committee can only present brief abstracts of the published volume. These have, however, been selected and arranged to include those facts which are likely to be of interest to the members of the Association. The abstract thus arranged is submitted as an appendix to this report.

6. Your committee, having completed the work for which it was appointed, and having hereby rendered its report to the Association, asks that it now be discharged.

Respectfully submitted,

F. H. CLARK,
C. H. QUEREAU,
H. H. VAUGHAN,
Committee.

CHICAGO, April, 1906.

* It is the understanding of your committee that an edition of 1,000 copies has been issued and that 500 copies have already been distributed. The remaining number have been deposited with Mr. D. S. Newhall, Purchasing Agent, Pennsylvania Railway Company, Broad Street Station, Philadelphia, from whom they may be obtained at a nominal price.

APPENDIX.

THE TESTS AND THEIR RESULTS.*

7. CONCERNING GENERAL CONDITIONS.— The fuel used for all tests was a bituminous coal of high quality. The heating value of one pound of dry coal averaged more than 14,000 B. T. U. Its composition was as follows:

Fixed carbon	75.85
Volatile combustible	16.25
Ash	7.00
Moisture	.90

Great care was taken to have the coal fired as uniformly as possible, and to this end certain selected men served continuously in the capacity of firemen.

All locomotive tests were run in accord with a fixed schedule of speed. To avoid irregularities arising from differences in diameter of drivers, the speeds of this schedule were selected with reference to the revolutions of the drivers. The standard speeds for freight locomotives were 40, 80, 120 and 160 revolutions per minute, and for passenger locomotives 80, 120, 160, 240 and 320 revolutions. The preparations for observing the action of a locomotive during a test were elaborate, and instruments occupied similar positions on all machines. The thoroughness which characterized the work may be judged from the fact that the log sheets for each test contained 399 items, many of which were the averaged values of many observations.

8. THE LOCOMOTIVES TESTED.— Eight locomotives were tested, four having been designed for freight and four for passenger service. Two of the freight locomotives were simple and two were compound, while all of the passenger locomotives were of the four-cylinder balanced compound type, one being of French design and manufacture, one of German and two of American. A summary of the locomotives tested is as follows:

* For a description of the testing plant, see "Locomotive Testing Plant," Vol. XXV, page 827.

THE LOCOMOTIVES TESTED.

Presented for test by	Designating Number	Service	Wheel Arrangement	Description	By whom manufactured
P. R. R.	1,499	Freight	2–8–0	Simple.	Pa. Railroad Company.
L. S. & M. S. Ry.	734	Freight	2–8–0	Simple.	American Loco. Co.
Mich. Central.	585	Freight	2–8–0	2-cylinder compound	American Loco. Co.
A. T. & S. F. Railway	929	Freight	2–10–2	2-cylinder tandem compound	Baldwin Loco. Works.
A. T. & S. F. Railway.	535	Passenger	4–4–2	4-cylinder balanced compound	Baldwin Loco. Works.
Hanover Loco. Works	628	Passenger	4–4–2	4-cylinder balanced compound with superheater.	Hanover Loco. Works.
N. Y. C. & H. R. R. R	3,000	Passenger	4–4–2	4-cylinder balanced compound	American Loco. Co.
P. R. R.	2,512	Passenger	4–4–2	4-cylinder balanced compound	Alsacienne Co.

THE LOCOMOTIVES TESTED AND RESULTS OBTAINED FROM THEM.

9. Tests of Consolidation Locomotive, Pennsylvania Railroad Company.— The first locomotive placed on the testing plant was No. 1499, owned by the Pennsylvania Railroad Company. It is of the simplest consolidation (2-8-0) type, and is the standard heavy freight locomotive used on the Pennsylvania Railroad. It is known as the "H-6a" type, according to the railroad company's classification. The locomotive was new and had not been thoroughly broken in before being tested. The first official test was made on May 25, the locomotive having been run previously for three weeks in order to break in the plant. The principal dimensions and details of the locomotive are shown in the following table:

Total weight, pounds	194,200
Weight on drivers, pounds	173,200
Cylinders (simple), inches	22 by 28
Diameter of drivers, inches	56
Fire-box heating surface, square feet	1,664
Heating surface in tubes (water side), square feet	2,667.27
Total heating surface (based on water side of tubes), square feet	2,843.67
*Total heating surface (based on fire side of tubes), square feet	2,482.26
Grate area, square feet	49.2
Boiler pressure, square feet	205
Valves	Richardson balanced.
Link motion	Stephenson.
Fire box, type	Belpaire.
No. of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.5

The maximum tractive effort was 39,773 pounds, which was calculated on the assumption that eighty per cent of the boiler pressure (205 pounds) was available as mean effective pressure at starting. On this basis the ratio of weight on drivers to maximum tractive effort was 4.35 : 1.

A summary of the results obtained from this locomotive is given in Table I.

* Used in calculations.

TABLE I.

SUMMARY OF DATA. PENNSYLVANIA RAILROAD LOCOMOTIVE No 1499.

BUILT AT JUNIATA SHOPS OF THE PENNSYLVANIA RAILROAD, ALTOONA, PA., MARCH, 1904.

	RUNNING CONDITIONS.				BOILER PERFORMANCE.					POWER.			WATER AND FUEL CONSUMPTION. Pounds.		
NUMBER OF TEST	REVOLUTIONS PER MINUTE.	MILES PER HOUR	CUT OFF, PERCENT OF STROKE.	THROTTLE OPENING.	EQUIVALENT EVAPORATION. POUNDS PER HOUR.	EQ. EVAP. PER SQ. FT. HEATING SURFACE PER HOUR. POUNDS.	BOILER HORSE POWER.	POUNDS OF DRY COAL PER HOUR.	EQUIV. EVAP. PER POUND OF DRY COAL.	INDICATED HORSE POWER.	MACHINE FRICTION HORSE POWER.	DYNAMOMETER PULL. POUNDS.	STEAM PER I.H.P. PER HOUR. POUNDS.	COAL PER I.H.P. PER HOUR. POUNDS.	COAL PER D.H.P. PER HOUR. POUNDS.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
110	40.3	6.7	22.44	FULL.	12,870	5.18	373	1116	11.53	366	85	15,706	28.33	2.94	3.84
111	40.4	6.7	30.45	"	15,372	6.19	445	1368	11.24	454	81	20,864	27.29	2.91	3.54
103	92.7	15.4	22.80	"	20,581	8.29	596	2089	9.85	650	133	12,587	25.51	3.13	3.94
109	81.6	13.5	20.88	"	18,375	7.40	533	2094	8.78	588	106	13,314	25.31	3.47	4.24
112	79.7	13.2	29.24	"	22,825	9.20	662	2767	8.25	779	150	17,831	23.92	3.48	4.30
118	80.7	13.4	39.34	"	28,102	11.32	815	3448	8.15	930	141	22,078	24.70	3.63	4.28
108	79.7	13.2	41.44	"	26,895	10.83	780	3940	6.83	895	162	20,779	24.69	4.33	5.29
116	120.1	20.0	31.33	"	27,856	11.22	807	3516	7.92	975	187	14,813	23.43	3.54	4.38
115	120.6	20.0	33.96	"	29,900	12.04	867	4041	7.40	1036	187	15,883	23.74	3.84	4.69
102	160.3	26.6	22.16	"	24,410	9.83	707	3271	7.46	803	188	8,663	24.78	4.00	5.22
105	157.6	26.2	28.03	"	27,513	11.08	797	3829	7.19	951	260	9,929	23.73	3.96	5.43
113	158.7	26.4	30.12	"	28,427	11.45	824	4001	7.11	968	206	10,835	24.17	4.07	5.17
106	160.9	26.7	32.91	"	30,943	12.47	897	4627	6.69	1050	276	10,863	24.15	4.34	5.89
117	160.6	26.7	35.30	PARTIAL	30,747	12.39	891	4163	7.39	1024	248	10,902	24.69	4.00	5.28
101	160.5	26.7	42.14	"	28,203	11.36	817	4252	6.63	852	203	9,118	27.30	4.93	6.48
104	160.8	26.7	45.09	"	28,424	11.45	824	3882	7.32	803	207	8,366	29.19	4.77	6.44
114	160.8	26.7	52.05	"	28,593	11.51	828	3723	7.68	682	170	7,182	34.62	5.40	7.19

THE BOILER PRESSURE WAS FROM 172 TO 203 POUNDS PER SQUARE INCH.

10. Tests of Consolidation Locomotive, Lake Shore & Michigan Southern Railway Company.—The second locomotive tested was No. 734, a two-cylinder simple locomotive, owned by the Lake Shore & Michigan Southern Railway Company and built at the Brooks Locomotive Works. It was of the 2-8-0 type and known as Class B-1, according to the railroad company's classification.

Twenty-one tests were made, the first on July 2 and the last on August 2. The total number of working days consumed in making these tests was twenty-nine, twelve of which were lost on account of difficulties experienced with the plant, and six days on account of difficulties with the locomotive.

The principal dimensions and the details of the locomotive are shown in the following table:

Total weight, pounds	181,300
Weight on drivers, pounds	162,600
Cylinders (simple), inches	21 by 30
Diameter of drivers, inches	63
Fire-box heating surface, square feet	218.92
Heating surface in tubes (water side), square feet	2,638.97
Total heating surface (based on water side of tubes), square feet	2,857.89
*Total heating surface (based on fire side of tubes), square feet	2,541.22
Grate area, square feet	33.76
Boiler pressure, pounds	200
Valves	Allen-Richardson.
Link motion	Stephenson.
Fire box, type	Narrow, on top of frames.
Number of tubes	338
Outside diameter of tubes, inches	2
Length of tubes, inches	178.94

The maximum tractive effort was 33,616 pounds, which was calculated on the assumption that eighty per cent of the boiler pressure (200 pounds) was available as mean effective pressure at starting. On this basis the ratio of weight on drivers to maximum tractive effort was 4.84 : 1.

A summary of the results obtained from the locomotive is given in Table II.

* Used in calculations.

TABLE II.

SUMMARY OF DATA. LAKE SHORE AND MICHIGAN SOUTHERN LOCOMOTIVE No. 73

BUILT BY BROOKS LOCOMOTIVE WORKS, DUNKIRK, N.Y., 1900.

	RUNNING CONDITIONS.				BOILER PERFORMANCE.					POWER			WATER AND FUEL CONSUMPTION POUNDS		
NUMBER OF TEST	REVOLUTIONS PER MINUTE	MILES PER HOUR.	CUT-OFF PERCENT OF STROKE	THROTTLE OPENING.	EQUIVALENT EVAPORATION POUNDS PER HOUR.	EQ. EVAP. PER SQ. FOOT OF HEATING SURFACE PER HOUR. POUNDS.	BOILER HORSE POWER	POUNDS OF DRY COAL PER HOUR	EQUIV. EVAP. PER POUND OF COAL	INDICATED HORSE POWER.	MACHINE FRICTION HORSE POWER	DYNAMOMETER PULL POUNDS.	STEAM PER I.H.P. PER HOUR. POUNDS.	COAL PER I.H.P. PER HOUR POUNDS	COAL PER D.H.P. PER HOUR POUNDS
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
201	40.3	7.6	19.1	FULL.	11,122	4.38	322	1109	10.0	299	67	11,531	29.56	3.53	4.55
202	40.5	7.6	30.7	"	15,162	5.97	439	1412	10.7	434	33	19,860	27.78	3.10	3.36
203	40.1	7.5	41.3	"	18,599	7.32	539	2027	9.2	550	59	24,522	27.31	3.65	3.98
204	80.0	15.0	43.9	"	28,500	11.21	826	4468	6.3	901	84	20,444	26.11	4.88	5.39
205	80.5	15.1	17.3	"	16,864	6.64	489	1781	9.5	527	64	11,515	25.89	3.28	3.73
206	80.1	15.0	30.7	"	23,580	9.28	683	2729	8.6	783	51	18,288	24.55	3.41	3.65
208	80.0	15.0	40.7	"	29,453	11.59	854	4152	7.1	962	68	22,371	24.93	4.22	4.54
209	159.3	29.9	21.1	"	26,780	10.54	776	3435	7.7	866	80	9,861	25.11	3.86	4.25
210	159.9	30.0	23.3	"	28,713	11.30	832	4096	7.0	954	103	10,642	24.67	4.22	4.72
211	160.0	30.0	29.0	"	31,361	12.34	909	5061	6.2	995	134	10,755	26.04	5.02	5.80
212	160.3	30.0	27.4	"	30,620	12.05	887	4695	6.5	1054	157	11,188	23.92	4.38	5.16
213	160.4	30.1	39.8	PARTIAL	29,710	11.69	861	4505	6.6	887	85	9,998	27.64	5.01	5.54
214	39.6	7.4	19.4	FULL.						306	54	12,725			
215	80.1	15.0	19.7	"						569	94	11,847			
216	79.5	14.9	40.1	"						995	81	22,001			
217	159.2	29.8	38.5	PARTIAL	29,190	11.49	846	3975	7.3	799	40	9,540	30.41	4.91	5.17
218	160.1	30.0	39.0	"	29,352	11.55	851	4509	6.5	865	22	10,538	28.01	5.14	5.28
219	158.8	29.8	30.9	"	28,712	11.29	832	4079	7.0	923	86	10,546	25.53	4.34	4.78
220	160.0	30.0	24.6	"	28,280	11.13	820	3950	7.2	942	135	10,096	24.67	4.12	4.81
221	118.9	22.3	35.7	FULL						1098	141	16,104			
222	119.4	22.4	37.5	"						1098	98	16,744			

THE BOILER PRESSURE WAS FROM 178 TO 204 POUNDS PER SQUARE INCH.

11. Tests of Consolidation Locomotive, Michigan Central Railroad Company.— The third locomotive tested was No. 585, owned by the Michigan Central Railroad Company and built by the American Locomotive Company at its Schenectady Works. It was of the 2-8-0 type and known as Class W, according to the railroad company's classification. This locomotive was a two-cylinder cross compound.

It was on the plant from August 10 to August 27; work on the dynamometer consuming the time from August 3 to 10. In the twenty-two working days fourteen tests were made, twelve days being lost on account of the plant and three days on account of the locomotive.

The principal dimensions and details of the locomotive are shown in the following table:

Total weight, pounds	189,000
Weight on drivers, pounds	164,500
Cylinders (compound), inches	23 and 35 by 32
Diameter of drivers, inches	63
Fire-box heating surface, square feet	165.69
Heating surface in tubes (water side), square feet	3,015.34
Total heating surface (based on water side of tubes), square feet	3,181.03
*Total heating surface (based on fire side of tubes), square feet	2,819.20
Grate area, square feet	49.43
Boiler pressure, pounds	210
Valves, high pressure, piston; low pressure, Allen-Richardson.	
Link motion	Stephenson.
Fire box, type	Radial stay, wide.
Number of tubes	383
Outside diameter of tubes, inches	2
Length of tubes, inches	190.38

The maximum tractive effort was 45,613 pounds working simple and 31,823 pounds working compound. The ratio of weight on drivers to maximum tractive effort when working simple was 3.61 : 1, and when working compound, 5.17 : 1.

A summary of the results obtained from this locomotive is given in Table III.

* Used in calculations.

TABLE III.

SUMMARY OF DATA — MICHIGAN CENTRAL LOCOMOTIVE No. 585.

BUILT BY THE AMERICAN LOCOMOTIVE CO. SCHENECTADY, N.Y., 1902.

	Running Conditions.				Boiler Performance.					Power.			Water and Fuel Consumption. Pounds.		
Number of Test	Revolutions per Minute	Miles per Hour.	Cut off Percentage of Stroke H.P.C.	Throttle Opening.	Equivalent Evaporation Pounds per Hour.	Eq. Evap. per Sq. Ft Heating Surface per Hour. Pounds.	Boiler Horse Power	Pounds of Dry Coal per Hour.	Equiv. Evap. per Pound of Dry Coal.	Indicated Horse Power.	Machine Friction Horse Power	Dynamometer Pull. Pounds.	Steam per I.H.P. per Hour. Pounds.	Coal per I.H.P. per Hour. Pounds.	Coal per D.H.P. per Hour. Pounds
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
301	40.0	7.5	43.1	Full	11,180	3.97	324	1027	10.89	442	31	20,605	20.20	2.22	2.38
302	40.0	7.5	45.3	"	11,966	4.25	347	1013	11.82	477	35	22,149	20.09	2.03	2.19
303	40.0	7.5	48.6	"	12,884	4.57	373	1073	12.01	512	30	24,105	20.27	2.01	2.14
305	80.0	15.0	45.7	"	20,205	7.17	586	1770	11.41	841	67	19,393	19.54	2.05	2.23
306	80.2	15.0	42.2	"	18,178	6.45	527	1683	10.80	735	59	16,879	20.15	2.23	2.42
308	80.0	15.0	52.8	"	22,476	7.97	651	2087	10.77	932	61	21,815	19.69	2.19	2.34
309	80.0	15.0	57.5	"	25,501	9.05	739	2559	9.97	1041	61	24,539	20.03	2.41	2.56
311	117.9	22.1	50.6	"						998	97	15,297			
312	160.0	30.0	49.6	"	25,075	8.89	727	2687	9.24	890	160	9,138	23.18	2.96	3.61
313	160.0	30.0	50.7	"	27,876	9.78	799	2767	9.97	992	168	10,308	22.80	2.74	3.30
316	160.0	30.0	64.1	"	29,700	10.53	861	3876	7.66	1001	142	10,762	24.43	3.82	4.44
317	160.0	30.0	51.5	Partial	24,538	8.70	711	2444	10.04	910	183	9,102	21.98	2.62	3.28
318	160.0	30.0	60.3	"	26,864	9.53	779	2738	9.81	938	176	9,530	23.56	2.87	3.54
319	160.0	30.0	66.0	"	27,370	9.71	793	2638	10.38	934	196	9,236	24.14	2.79	3.52

THE BOILER PRESSURE WAS FROM 175 TO 211 POUNDS PER SQUARE INCH.

12. TESTS OF "SANTA FE" TYPE LOCOMOTIVE, ATCHISON, TOPEKA & SANTA FE RAILWAY SYSTEM.— The fourth locomotive tested was No. 929, owned by the Atchison, Topeka & Santa Fe Railway System and built at the Baldwin Locomotive Works. It was of the 2-10-2 type and known as Class 900, according to the railroad company's classification. It was a four-cylinder compound.

This locomotive occupied the time from August 28 to September 17. In these twenty-one working days nine tests were run, the throttling tests being omitted, as it was decided that the information would not be valuable on compound locomotives.

Four days were lost on account of difficulties with the plant, one on account of difficulties with the locomotive and eight and one-half days due to trouble experienced in getting the locomotive to the plant.

An accident reduced the number of available brakes to seven, which was unfortunate, as this locomotive was very powerful and, with the low and varying water pressure in the mains during the period of the tests, it was possible to make tests only at powers below the full capacity of the locomotive. Its calculated tractive power was 63,612 pounds, and the highest draw-bar pull obtained in any test was 32,532 pounds.

Tests were only run at 40, 60 and 80 revolutions per minute. They were not, therefore, complete, nor conclusive, as the limits of the boiler capacity could not be ascertained.

The principal dimensions and the details of the locomotive are shown in the following table:

Total weight, pounds	285,740
Weight on drivers, pounds	233,760
Cylinders (compound), inches	19 and 23 by 32
Diameter of drivers, inches	56.5
Fire-box heating surface, square feet	216.36
Heating surface in tubes (water side), square feet	4,601.00
Total heating surface (based on water side of tubes), square feet	4,817.36
*Total heating surface (based on fire side of tubes), square feet	4,306.13
Grate area, square feet	58.41
Boiler pressure, pounds	225
Valves	Piston.
Link motion	Stephenson.
Fire box, type	Radial stay.
Number of tubes	393
Outside diameter of tubes, inches	2.25
Length of tubes, inches	238.5

The maximum tractive effort was 73,177 pounds, working simple, and 63,612 pounds working compound. The ratio of weight on drivers to maximum tractive effort, working simple, was 3.19 : 1, and when working compound, 3.67 : 1.

A summary of results obtained from this locomotive is given in Table IV.

* Used in calculations.

TABLE IV.

SUMMARY OF DATA — ATCHISON, TOPEKA AND SANTA FE LOCOMOTIVE No. 929.

BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA., 1903.

	Running Conditions.				Boiler Performance.					Power.			Water and Fuel Consumption. Pounds		
Number of Test	Revolutions per Minute	Miles per Hour	Cut off, Per Cent of Stroke H.P.C.	Throttle Opening	Equivalent Evaporation, Pounds per Hour.	Eq. Evap. per Sq. Ft. Heating Surface per Hour Pounds	Boiler Horse Power	Pounds of Dry Coal per Hour.	Equiv. Evap. per Pound of Dry Coal.	Indicated Horse Power.	Machine Friction Horse Power	Dynamometer Pull Pounds	Steam per I.H.P. per Hour. Pounds.	Coal per I.H.P. per Hour Pounds	Coal per D.H.P. per Hour. Pounds.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII	XIII	XIV	XV	XVI
401	40.0	6.7	26.6	FULL.	12,926	3.00	375	1111	11.63	392	57	18,680	26.47	2.73	3.20
402	40.0	6.7	33.9	"	15,705	3.65	455	1465	10.72	511	67	24,784	24.80	2.78	3.20
403	40.0	6.7	40.8	"	18,273	4.24	530	1751	10.43	634	76	31,131	23.38	2.69	3.06
405	80.0	13.4	28.8	"	18,414	4.28	534	1666	11.05	631	122	14,224	23.67	2.57	3.19
407	80.0	13.4	41.4	"	27,901	6.48	809	2651	10.52	1089	124	26,929	20.98	2.39	2.70
408	81.3	13.6	51.4	"	36,813	8.55	1067	4299	8.56	1258	120	31,240	24.04	3.37	3.74
410	60.0	10.1	26.1	"	16,350	380	474	1437	11.38	511	101	15,285	25.80	2.73	3.39
411	60.0	10.1	33.7	"	20,195	4.69	585	1935	10.44	705	107	22,279	23.22	2.68	3.16
412	60.6	10.2	41.9	"	23,814	5.53	690	2381	10.00	889	101	29,005	21.84	2.63	2.96

THE BOILER PRESSURE WAS FROM 213 TO 217 POUNDS PER SQUARE INCH.

13.— Tests of De Glehn Atlantic Type Locomotive, Pennsylvania Railroad Company.— The fifth locomotive tested was No. 2512, owned by the Pennsylvania Railroad Company and built from the designs of Messrs. De Glehn and Du Bosquet, by the Société Alsacienne de Constructions Mecaniques, at Belfort, France. The locomotive was a four-cylinder balanced compound of the 4-4-2 type, and being the only locomotive of this type in this country, it has not been classified by the railroad company.

It was, with the exception of a few unimportant modifications, an exact duplicate of a number of locomotives furnished to the Northern Railway of France by the same builders. It was the only one tested having Serve ribbed tubes in the boiler.

In the "De Glehn" type the low-pressure cylinders are between the frames, and the high-pressure cylinders are outside the frames. The low-pressure cylinders are side by side and drive inside cranks set quartering on the forward driving axle. The high-pressure cylinders connect with outside crank pins in the drivers of the second driving axle.

The high-pressure cylinders are placed back on the frames in relation to the low-pressure cylinders, so that the main rods of the former are but 15½ inches longer than those of the latter.

This locomotive had a separate valve gear for both high-pressure and low-pressure cylinders, and the cut-off in the low-pressure cylinders could be varied independently of the high-pressure cut-off.

Both high-pressure cylinders exhausted into a combined receiver and steam chest of 14.5 cubic feet capacity. A variable nozzle having an area of 17.5 to 43.5 square inches and operated from the cab, controlled the exhaust blast and was varied to suit the points of cut-off which were used.

When operated simple, the high-pressure cylinders exhausted to the atmosphere and an auxiliary throttle admitted live steam to the low-pressure cylinders.

The front flue sheet was made of steel about 1 inch thick and the back sheet was copper about 1 5-16 inches thick.

The fire box was made of copper, both sides and crown sheet being a single piece ⅝ of an inch thick. The four top rows of stay bolts were manganese bronze, the others copper, and all were drilled.

This locomotive was placed on the testing plant twice, the first period being from November 25 to December 3, a total of thirty days, during which time ten tests were made. In the first period of twenty-one days six tests were obtained; the most serious delay being due to parts of the locomotive running hot when high speeds were attempted.

Seven and one-half days were lost on account of heating of rod brasses, chiefly at the back end of the low-pressure main rod journals. The low-pressure rods were on the inside cranks, where the brasses were necessarily narrow, and hence, the pressure per unit of area was high.

The whole locomotive was unusually steady at all speeds, having very little motion of any kind.

On October 7, when the test at 320 revolutions was attempted, the left front driving box ran hot after seven minutes, and it was necessary to stop. The construction of this locomotive was such that it was impossible to examine and repack the driving-box collars without dropping the driving wheels. Not having any drop pit, this was impossible at the testing plant.

The locomotive was sent to the Terre Haute shops of the Vandalia Line, repaired and run on the road until it was thought to be in good condition, and was then returned to St. Louis.

After tests on the Atchison, Hanover and New York Central locomotives were completed, the De Glehn was again placed on the testing plant, on November 25, and was taken off on December 3. In this period of nine days, four tests were obtained. Considerable difficulty was encountered in getting the locomotive to steam, it having been impossible to run at cut-offs as long as those obtained on the road.

The coal used was soft, and readily broke into small pieces. There was no shaking arrangement in the grates and if the nozzle was decreased in size to increase the draft and clear the fire, there was a tendency to fill up the smoke box with cinders. For these reasons, the indicated horsepowers obtained were not as large as the maximum reported from road tests.

This locomotive will be very carefully tested on the testing plant as soon as it is erected at Altoona, with a view to developing the value of this system of compounding.

After November 29 no more tests were obtained, due to heating of the back ends of the main rods, and the locomotive was removed from the plant on December 3. In these twenty-six working days, two and one-half days were lost on account of difficulties experienced with the plant and seventeen due to troubles with the locomotive.

The principal dimensions and the details of the locomotive are shown in the following table:

Total weight, pounds	164,000
Weight on drivers, pounds	87,850
Cylinders (compound), inches	14 3-16 and 23 11-16 by 25¼
Diameter of drivers, inches	80
Fire box heating surface, square feet	177.28
Heating surface in tubes (water side), square feet	1,468.87
Total heating surface (based on water side of tubes), square feet	1,646.15
Total heating surface (based on fire side of tubes), square feet	2,656.48
Grate area, square feet	33.39
Boiler pressure, pounds per square inch	225
Valves	"D" slide, H. P. balanced; L. P., not balanced.
Valve motion	Walschaert.
Fire box, type	Belpaire.
Number of tubes (Serve)	139
Outside diameter of tubes, inches	2¼
Length of tubes, inches	176.14

The maximum tractive effort was 22,698 pounds working simple and 16,700 pounds working compound, which was calculated on the assumption that eighty per cent of the boiler pressure (225 pounds) was available as mean effective pressure at starting. On this basis the ratio of weight on drivers to maximum tractive effort was 3.87 : 1 working simple, and 5.26 : 1 working compound.

A summary of the results obtained from this locomotive is given in Table V.

TABLE V.

SUMMARY OF DATA. PENNSYLVANIA RAILROAD LOCOMOTIVE No. 2512.

BUILT BY THE SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES, BELFORT, FRANCE, 1904.

					BOILER PERFORMANCE.					POWER.			WATER AND FUEL CONSUMPTION. POUNDS.		
NUMBER OF TEST				THROTTLE OPENING	EQUIVALENT EVAPORATION. POUNDS PER HOUR	EQ EVAP. PER SQ FT HEATING SURFACE PER HOUR POUNDS	BOILER HORSE POWER	POUNDS OF DRY COAL PER HOUR	EQUIV EVAP PER POUND OF DRY COAL	INDICATED HORSE POWER	MACHINE FRICTION HORSE POWER	DYNAMOMETER PULL. POUNDS.	STEAM PER I.H.P. PER HOUR. POUNDS	COAL PER I.H.P. PER HOUR POUNDS	COAL PER D.H.P. PER HOUR POUNDS
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
501	150.0	49.1	24.9 / 92.1	FULL	8,416	3.17	244	690	12.19	310	33	5,443	21.20	2.09	2.34
502	150.0	49.1	59.1 / 69.0	"	11,580	4.36	336	1005	11.53	496	56	8,615	18.60	1.94	2.19
503	160.0	52.5	34.7 / 57.5	"	13,089	4.93	379	1157	11.31	524	81	4,343	19.95	2.12	2.52
504	160.0	52.5	41.5 / 57.7	"	13,810	5.20	400	1259	10.97	524	71	4,448	21.15	2.31	2.67
507	160.0	52.5	39.4 / 60.1	"	20,091	7.56	582	2247	8.94	809	199	5,976	19.60	2.69	3.57
508	160.0	52.5	48.7 / 69.8	"	23,999	9.04	696	3038	7.90	945	102	8,262	20.67	3.14	3.52
510	240.0	57.4	27.7 / 50.0	"	16,273	6.13	472	1761	9.24	597	243	2,309	21.95	2.86	4.83
511	240.0	57.4	29.8 / 57.2	"	18,933	7.13	549	2395	7.90	653	92	3,664	22.69	3.52	4.10
512	240.0	57.4	34.2 / 62.2	"	22,086	8.32	640	2641	8.36	802	149	4,268	21.62	3.17	3.90
513	280.0	67.0	29.2 / 57.9	"	23,453	8.83	680	2897	8.10	682	172	2,857	27.05	4.10	5.48

THE BOILER PRESSURE WAS FROM 206 TO 220 POUNDS PER SQUARE INCH.

14. Tests of Atlantic Type Locomotive, Atchison, Topeka & Santa Fe Railway System.— The sixth locomotive tested was No. 535, owned by the Atchison, Topeka & Santa Fe Railway System, and was built at the Baldwin Locomotive Works. It was of the 4-4-2 type and known as Class 507 according to the railroad company's classification.

This was a Vauclain four-cylinder compound locomotive of the type introduced by the Baldwin Locomotive Works. The two low-pressure cylinders were outside of the frames and the two high-pressure cylinders between them. All four cylinders were connected to the front axle. The high-pressure crossheads were connected to a cranked axle in which the crank pins were set quartering or 90° apart. The low-pressure crossheads were connected to crank pins 90° apart in the front drivers. On either side of the locomotive there was a high and low pressure cylinder connected to cranks set opposite or at 180° to each other. The high and low pressure cylinders were in line across the locomotive so that the high and low pressure connecting rods were of the same length.

The cut-off in the high and low pressure cylinders could not be varied independently, as the valves for each set of high and low pressure cylinders were actuated by a single valve gear.

The first official test on this locomotive was made on October 12.

Locomotive No. 535 occupied the time from October 9 to November 1, a period of twenty-four days. During that period eleven tests were made; the work being delayed by hot inside crank brasses on the locomotive. Four days were lost by troubles due to the plant and eight on account of the locomotive.

On October 27 an attempt was made to run a test at 320 revolutions, but after two minutes the babbitt melted out of the inside crank brasses. New brasses were put in and this test was again tried the next day, with the same result. As it appeared unlikely that a test could be run at 320 revolutions, a test at 280 revolutions was tried, with success. On October 31 a test at 320 revolutions failed after ten minutes, for the same reason as the others, and on November 1 the same thing occurred again. It was then decided to remove the locomotive from the plant, as four attempts at tests had failed at this speed, and it was evidently impossible to run it cool at this speed, on the testing plant.

This locomotive vibrated considerably at 240 revolutions, the movements of the pilot being about eight-tenths of an inch. The wires that were run under the wheels to determine the effect of the counter-balance weights on rail pressure, showed that at 320 revolutions the driving wheel lifted from the supporting wheel a height of at least six one-hundredths of an inch. A tendency to run to the right side was also noticed, the driving wheels bearing so hard against the right supporting wheels that the flanges of the drivers were badly cut. The locomotive was jacked over to the left, and wooden wedges driven in between the frame and trailer to hold it over, but the vibration of the locomotive soon loosened the wedges and the cutting of the flanges would commence again. The locomotive was

squared, the wheels trammed and the supporting wheels were correctly set. The circumference of the driving wheels on the right side was two-thousandths of a foot larger than on the left side.

The principal dimensions and the details of the locomotive are shown in the following table:

Total weight, pounds	201,500
Weight on drivers, pounds	99,200
Cylinders (compound), inches	15 and 25 by 26
Diameter of drivers, inches	79
Fire box heating surface, square feet	220.3
Heating surface in tubes (water side), square feet	3,016.71
Total heating surface (based on water side of tubes), square feet	3,237.01
*Total heating surface (based on fire side of tubes), square feet	2,902.05
Grate area, square feet	48.36
Boiler pressure, pounds	220
Valves	Piston.
Link motion	Stephenson.
Fire box, type	Wagon top.
Number of tubes	273
Outside diameter of tubes, inches	2.25
Length of tubes, inches	225.14

The maximum tractive effort was 26,182 pounds working simple, and 19,245 pounds working compound, which was calculated on the assumption that eighty per cent of the boiler pressure (220 pounds) was available as mean effective pressure at starting. On this basis the ratio of weight on drivers to maximum tractive effort was 3.79 : 1 working simple, and 5.15 : 1 working compound.

A summary of the results obtained from this locomotive will be given in Table VI.

* Used in calculations.

TABLE VI.

SUMMARY OF DATA. ATCHISON, TOPEKA AND SANTA FE LOCOMOTIVE No. 535.

BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA, PA., 1904.

	Running Conditions.				Boiler Performance.					Power			Water and Fuel Consumption. Pounds		
Number of Test.	Revolutions per Minute.	Miles per Hour	Cut off Percent of Stroke H.P.C.	Throttle Opening.	Equivalent Evaporation Pounds per Hour	Eq. Evap. per Sq. Ft. Heating Surface per Hour Pounds	Boiler Horse Power.	Pounds of Dry Coal per Hour	Equiv. Evap. per Pound of Dry Coal	Indicated Horse Power	Machine Friction Horse Power	Dynamometer Pull. Pounds.	Steam per I.H.P. per Hour Pounds	Coal per I.H.P. per Hour Pounds	Coal per D.H.P. per Hour Pounds
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
601	80.0	18.8	26.7	Full	10,656	3.67	309	875	12.17	356	53	6,058	23.67	2.34	2.75
602	80.0	18.8	31.0	"	13,012	4.48	377	1169	11.13	479	86	7,847	21.67	2.35	2.86
603	80.0	18.8	37.6	"	15,638	5.39	453	1381	11.33	570	69	9,998	21.91	2.34	2.66
604	80.0	18.8	53.0	"	20,713	7.14	600	2058	10.06	808	166	12.815	20.56	2.48	3.12
605	160.0	37.6	36.1	"	21.128	7.28	612	2055	10.28	877	122	7,533	19.44	2.28	2.65
606	160.0	37.6	43.0	"	24,885	8.58	721	2468	10.09	1000	127	8,708	20.17	2.42	2.77
607	160.0	37.6	50.5	"	30,900	10.65	896	3258	9.49	1296	181	11, 119	19.41	2.47	2.87
609	239.9	56.4	46.4	"	34,668	11.95	1005	4452	7.79	1414	392	6, 803	19.99	3.10	4.29
610	240.0	56.4	52.9	"	39,539	13.62	1146	5831	6.78	1549	245	8,679	20.82	3.72	4.41
611	240.0	56.4	51.3	"	40,964	14.11	1187	5701	7.19	1621	352	8,444	20.48	3.47	4.43
613	280.0	65.8	47.7	"	37,463	12.91	1086	5104	7.34	1460	562	5,120.	20.73	3.45	5.60

THE BOILER PRESSURE WAS FROM 216 TO 222 POUNDS PER SQUARE INCH.

15. TESTS OF ATLANTIC TYPE LOCOMOTIVE HANNOVERSCHE MASCHINENBAUACTIEN-GESELLSCHAFT.— The seventh locomotive tested was No. 628, built by the Hannoveresche Maschienenbau-Actien-Gesellschaft, vormals Georg Egestorff, Linden vor Hannover, Germany, and was presented for test by the builders. This locomotive was built for the Hannover directorate of the Royal Prussian Railway Administration (Koeniglich Preuss. Eisenbahm Verwaltung, Direktion Hannover) and was delivered to them at the close of the exposition.

The locomotive was a four-cylinder balanced compound with superheater, and was known as the S-8 Class, according to the railroad company's classification.

The valve motion was the Heusinger von Waldegg, otherwise known as the Walschaert modified by von Borries.

The four cylinders were set across the locomotive on the center line of the leading truck. The two high-pressure cylinders were between the frames, and the two low-pressure cylinders were outside the frames. The high and low pressure cylinders of each pair were cast in one piece with the corresponding steam chests, and the two groups of cylinders bolted together. The four cylinders were all connected to the forward axle. The cranks of the high-pressure cylinders, on one side, were set at 180° to each other.

This locomotive was equipped with a Pielock superheater, which consisted of a chamber in the shell of the boiler using a portion of the boiler tubes as superheating surface. It was located far enough from the fire box so that the tubes could not be overheated. The main part of the superheater consisted of a box into which the ends of the boiler tubes were lightly rolled. This box was divided into compartments by plates parallel to the tubes so as to get a long contact of the steam with the heating surface. The steam, at boiler pressure, passed into the superheater and then through the several compartments on its way to the cylinders.

This locomotive was on the testing plant from November 2 until November 12, a period of eleven days. In this time ten tests were made; all of the lost time, except half a day, being due to the locomotive.

The chief difficulty was caused by the inefficiency of the draft appliances. The fire did not burn evenly on the grate, being very intense next the flue sheet, under the brick arch, and very dull and without draft near the fire door.

There was no diaphragm plate or petticoat pipe in the front end, and the only way to adjust the draft was by changing the size of the nozzle. The height could not be changed, as no other exhaust nozzle pipes were on hand; the nozzle was made smaller, but this, of course, only increased the draft and did not make the fire burn more evenly.

The coal used was unlike that used in Germany. The locomotive was adjusted for burning the German fuel. In addition to the difficulty introduced by the different fuel, the locomotive was, undoubtedly, over-cylin-

dered for American practice. This is clearly shown by the following comparisons of ratios:

Locomotive Number.	Heating surface to cylinder volume.	Grate surface to cylinder volume.
628 (Hanover)	120.64	2.00
*628 (Hanover)	101.10	2.00
3,000 (N. Y. C.)	139.86	2.32
535 (A. T. & S. F.)	145.83	2.43
2,512 (P. R. R.)	154.14	1.93
†E2a (P. R. R.)	236.51	5.69

The tailpiece of the locomotive was made of a steel plate three-quarters of an inch thick, and covered the back of the frames, which were of the plate type. It was necessary to attach the fastenings for the dash pots to this plate, and above 280 revolutions per minute it was not sufficiently stiff to prevent excessive vibration; the action of the dash pots, therefore, did not protect the dynamometer.

The injectors on this locomotive did not admit of adjusting the feed as closely as American injectors do, so that the injectors had to be put on and off a great many times in the light tests. Consequently, the boiler pressure varied a good deal and considerable water was wasted at the injector overflow, but as the waste was measured it introduced no error.

The principal dimensions and the details of this locomotive are shown in the following table:

Total weight, pounds	133,350
Weight on driver, pounds	65,350
Cylinders (compound), inches	14. 5-32 and 22 by 23 5-8
Diameter of drivers, inches	78
Fire-box heating surface, square feet	105.59
Heating surface in tubes (water side), square feet, not including superheater	1,932.16
Total heating surface (based on water side of tubes), including superheater, square feet	1,753.15
‡Total heating surface (based on fire side of tubes), including superheater, square feet	1,753.15
Grate area, square feet	29.06
Boiler pressure, pounds per square inch	200
Valves	High pressure, piston; low pressure, Allen balanced.
Valve motion	Von Borries simplified Heusinger von Waldegg.
Fire box, type	Wide.
Number of tubes in boiler	241
Number of tubes in superheater	241
Outside diameter of tubes, inches	2
Length of tubes (not including superheater), inches	143.78
Length of tubes in superheater, inches	29.92

* Superheating surface not included.

† This locomotive was not tested, but ratios are given as typical of a simple Atlantic type locomotive.

‡ Used in calculations.

The maximum tractive effort was 19,459 pounds working simple, and 13,789 pounds working compound. The ratio of weight on drivers to maximum tractive effort when working simple was 3.36 : 1, and 4.74 : 1 working compound.

A summary of results of this locomotive is presented in Table VII.

TABLE VII.

SUMMARY OF DATA. HANOVER LOCOMOTIVE No. 628.

BUILT BY THE HANNOVERSCHE MASCHINENBAU-ACTIEN-GESELLSCHAFT, LINDEN VOR HANNOVER, GERMANY, 1904.

	RUNNING CONDITIONS.				BOILER PERFORMANCE.					POWER.			WATER AND FUEL CONSUMPTION. POUNDS.		
NUMBER OF TEST.	REVOLUTIONS PER MINUTE.	MILES PER HOUR.	CUT OFF PERCENT OF STROKE H.P.C.	THROTTLE OPENING.	EQUIVALENT EVAPORATION. POUNDS PER HOUR.	EQ. EVAP. PER SQ. FT. HEATING SURFACE PER HOUR POUNDS.	BOILER HORSE POWER	POUNDS OF DRY COAL PER HOUR.	EQUIV. EVAP. PER POUND OF DRY COAL.	INDICATED HORSE POWER.	MACHINE FRICTION HORSE POWER	DYNAMO-METER PULL POUNDS.	STEAM PER I.H.P. PER HOUR. POUNDS	COAL PER I.H.P. PER HOUR. POUNDS	COAL PER D.H.P. PER HOUR. POUNDS.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
701	80.0	18.6	35.2	FULL.	9,560	5.45	277	997	9.57	376	22	7136	18.09	2.44	2.60
702	80.0	18.6	44.9	"	12,000	6.85	348	1206	9.95	480	34	9016	17.82	2.34	2.52
705	160.0	37.1	37.6	"	14,720	8.40	427	1521	9.68	623	73	5552	16.81	2.27	2.57
706	160.1	37.1	43.2	"	16,696	9.52	484	1832	9.11	729	83	6516	16.60	2.38	2.69
707	160.0	37.1	47.8	"	19,789	11.29	574	2679	7.39	814	59	7622	17.86	3.15	3.40
708	160.0	37.1	47.4	"	19,725	11.25	572	2653	7.49	801	139	6690	18.16	3.21	3.88
709	240.0	55.7	35.3	"	14,620	8.34	424	1592	9.18	631	93	3624	16.67	2.38	2.80
710	239.4	55.6	38.8	"	16,670	9.51	483	2165	7.70	710	87	4203	17.36	2.96	3.37
711	240.0	55.7	46.4	"	20,834	11.88	604	3523	5.91	816	172	4339	18.80	4.19	5.31
712	280.3	65.0	35.8	"	19,913	11.36	577	2525	7.89	688	95	3422	21.29	3.53	4.09

THE BOILER PRESSURE WAS FROM 187 TO 204 POUNDS PER SQUARE INCH.

16. Tests of Atlantic Type Locomotive, New York Central & Hudson River Railroad.— The eighth locomotive tested was No. 3000, owned by the New York Central & Hudson River Railroad Company, and built by the American Locomotive Company at its Schenectady Works. It was of the 4-4-2 type and known as the I-1 Class according to the railroad company's classification. It was a four-cylinder balanced compound, designed by Mr. F. J. Cole.

This locomotive had two high-pressure cylinders between the frames, set a little forward of the smóke box. These high-pressure cylinders were connected to the forward axle, the cranks of which were set quartering. The low-pressure cylinders were outside the frames and connected to the second driving axle. Each outside crank pin was set 180° with its adjacent inside crank. This arrangement made necessary the use of shorter connecting rods on the inside than on the outside.

The cut-off in the high and low pressure cylinders could not be varied independently as the valve for each set of high and low pressure cylinders was actuated by a single valve gear.

The steam for the high-pressure cylinders passed through an opening in the saddle to a short pipe entering the top of the steam chest.

When working simple, a starting valve operated from the cab admitted live steam, at a reduced pressure, to the low-pressure cylinders.

The "Perfection" fuel economizer, consisting of special fire doors and means for admitting air above the fire, was used on this locomotive.

The locomotive was placed on the plant November 13 and removed November 24. During these twelve days, eleven tests were run. The last test was at a speed of 320 revolutions, or 75 miles an hour, and lasted for one hour. It was not possible to run any of the other locomotives at that speed for that length of time.

It ran very steadily and showed excellent counterbalancing in every way.

The principal dimensions and the details of the locomotive are shown in the following table:

Total weight, pounds	200,000
Weight on drivers, pounds	110,000
Cylinders (compound), inches	15½ and 26 by 26
Diameter of drivers, inches	151.69
Heating surface in tubes (water side), square feet	3,255.27
Total heating surface (based on water side of tubes), square feet	3,406.96
*Total heating surface (based on fire side of tubes), square feet	3,000.05
Grate area, square feet	49.90
Boiler pressure, pounds	220
Valves	Piston.
Link motion	Stephenson.
Fire box, type	Wide.
Number of tubes	390
Outside diameter of tubes, inches	2
Length of tubes, inches	191.29

* Used in calculations.

The maximum tractive effort was 27,890 pounds working simple, and 20,590 pounds working compound, which was calculated on the assumption that eighty per cent of the boiler pressure (220 pounds) was available as mean effective pressure at starting. On this basis the ratio of weight on drivers to maximum tractive effort was 3.94 : 1 working simple, and 5.34 : 1 working compound.

A summary of the results of this locomotive is presented in Table VIII.

TABLE VIII.

SUMMARY OF DATA. NEW YORK CENTRAL LOCOMOTIVE No. 3000.

BUILT BY THE AMERICAN LOCOMOTIVE CO., SCHNECTADY, N.Y., 1904.

	Running Conditions.				Boiler Performance.					Power			Water and Fuel Consumption Pounds		
Number of Test	Revolutions per Minute.	Miles per Hour	Cut off in Cylinder in % Stroke H.P.C.	Throttle Opening.	Equivalent Evaporation. Pounds per Hour	Eq. Evap. per Sq Foot Heating Surface per Hour. Pounds.	Boiler Horse Power	Pounds of Dry Coal per Hour.	Equiv. Evap. per Pound of Coal	Indicated Horse Power.	Machine Friction Horse Power.	Dynamometer Pull, Pounds.	Steam per I. H. P. per Hour Pounds.	Coal per I. H. P. per Hour Pounds	Coal per D.H.P. per Hour Pounds
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.	XVI.
801	79.8	18.7	56.0	FULL.	15,036	5.01	436	1287	11.7	567	179	7,781	20.78	2.17	3.17
802	80.0	18.8	45.9	"	18,703	6.23	542	1749	10.7	714	108	12,121	20.47	2.34	2.75
805	160.0	37.5	36.3	"	24,040	8.01	697	2357	10.2	967	72	8,940	19.60	2.34	2.53
806	160.0	37.5	43.7	"	31,142	10.38	903	3113	10.0	1253	76	11,766	19.95	2.44	2.60
807	160.0	37.5	57.1	"	39,872	13.29	1156	4880	8.2	1490	212	12,780	21.57	3.23	3.77
809	240.0	56.3	32.2	"	29,960	9.99	868	3024	9.9	1143	179	6,422	21.05	2.60	3.08
811	240.0	56.3	46.6	"	44,765	14.92	1297	5802	7.7	1630	160	9,796	22.18	3.52	3.90
812	240.0	56.3	53.7	"	48,025	16.34	1421	6694	7.3	1641	166	9,834	24.14	4.04	4.49
813	280.1	65.7	32.2	"	33,055	11.02	958	3476	9.5	1192	223	5,530	22.27	2.87	3.53
814	280.0	65.7	38.2	"	37,721	12.57	1093	3889	9.7	1369	180	6,788	22.19	2.80	3.23
815	320.0	75.0	41.0	"	38,973	12.99	1130	4928	7.9	1336	290	5,224	23.51	3.64	4.65

THE BOILER PRESSURE WAS FROM 209 TO 222 POUNDS PER SQUARE INCH.

A SUMMARY OF CONCLUSIONS.

17. Boiler Performance.

1. Contrary to a common assumption, the results show that when forced to maximum power, the large boilers delivered as much steam per unit area of heating surface as the small ones.

2. At maximum power, a majority of the boilers tested delivered 12 or more pounds of steam per square foot of heating surface per hour; two delivered more than 14 pounds; and one, the second in point of size, delivered 16.3 pounds. These values expressed in terms of boiler horse-power per square foot of heating surface are 0.34, 0.40 and 0.47, respectively.

3. The two boilers holding the first and second places with respect to weight of steam delivered per square foot of heating surface, are those of passenger locomotives.

4. The quality of steam delivered by the boilers of locomotives under constant conditions of operation is high, varying somewhat with different locomotives and with changes in the amount of power developed, between the limits of 98.3 per cent and 99 per cent.

5. The evaporative efficiency is generally maximum when the power delivered is least. Under conditions of maximum efficiency most of the boilers tested evaporated between 10 and 12 pounds of water per pound of dry coal. The efficiency falls as the rate of evaporation increases. When the power developed is greatest, its value commonly lies between limits of 6 and 8 pounds of water per pound of dry coal.

6. The observed temperature of the fire box under low rates of combustion lies between the limits of 1,400° F. and 2,000° F., depending apparently upon characteristics of the locomotive. As the rate of combustion increased, the temperature slowly increases, maximum values generally lying between the limits of 2,100° and 2,300° F.

7. The smoke-box temperature for all boilers, when worked at light power, is not far from 500° F. As the power is increased, the temperature rises, the maximum value depending upon the extent to which the boiler is forced. For the locomotives tested, it lies in most cases between 600° and 700° F.

8. With reference to grate area, the results prove beyond question that the furnace losses due to excess air are not increased by increasing the area. In general, it appears that the boilers for which the ratio of grate surface to heating surface is largest are those of greatest capacity.

9. A brick arch in the fire box results in some increase in furnace temperature and improves the combustion of the gases.

10. The loss of heat through imperfect combustion is in most cases small, except as represented by the discharge from the stack of solid particles of fuel.

11. Relatively large fire-box heating surface appears to give no advantage either with reference to capacity or efficiency. The fact seems to be that the tube heating surface is capable of absorbing such heat as may not be taken up by the fire box.

12. The value of the Serve tube over the plain tube of the same outside diameter, either as a means for increasing capacity or efficiency, was not definitely determined.

13. The draft in the front end for any given rate of combustion as measured in inches of water, depends upon the proportions of the locomotive and the thickness and condition of the fire. Under light power, its value may not exceed an inch, but it increases rapidly as the power is increased. Representative maximum values derived from the tests lie between the limits of 5 inches and 8.8 inches.

14. Insufficient openings in the ash pans and the mechanism of the front end, especially the diaphragm, are shown by the tests to lead to the dissipation of considerable portions of the draft force.

18. The Engine.

15. The indicated horse-power of the modern simple freight locomotive tested may be as great as 1,000 or 1,100; that of a modern compound passenger locomotive may exceed 1,600 horse-power.

16. The maximum indicated horse-power per square foot of grate surface lies, for the freight locomotives, between the limits of 31.2 and 21.1; for passenger locomotives, between the limits of 33.5 and 28.1.

17. The steam consumption per indicated horse-power hour necessarily depends upon the conditions of speed and cut-off. For the simple freight locomotives tested, the average minimum is 23.7. The consumption when developing maximum power is 23.8 and when under those conditions which proved to be the least efficient, 29.0.

18. The compound locomotives tested, using saturated steam, consumed from 18.6 to 27 pounds of steam per indicated horse-power hour. Aided by a superheater, the minimum consumption is reduced to 16.6 pounds of superheated steam per hour.

19. In general the steam consumption of simple locomotives decreases with increase of speed, while that of the compound locomotives increases. From this statement it appears that the relative advantages to be derived from the use of the compound diminish as the speed is increased.

20. Tests under a partially opened throttle show that when the degree of throttling is slight, the effect is not appreciable. When the degree of throttling is more pronounced, the performance is less satisfactory than when carrying the same load with a full throttle and a shorter cut-off.

19. The Locomotive as a Whole.

21. The percentage of the cylinder power which appears as a stress in the drawbar, diminishes with increase of speed. At 40 revolutions per minute, the maximum is 94 and the minimum 77; at 280 revolutions per minute, the maximum is 87 and the minimum 62.

22. The loss of power between the drawbar and the cylinder is greatly affected by the character of the lubricant. It appears from the tests that the substitution of grease for oil upon axles and crank pins increases the machine friction from seventy-five to one hundred per cent.

23. The coal consumption per dynamometer horse-power hour, for the simple freight locomotives tested, is at low speeds not less than 3.5 pounds nor more than 4.5 pounds, the value varying with the running conditions. At the highest speeds covered by the tests, the coal consumption for the simple locomotives increased to more than 5 pounds.

24. The coal consumption per dynamometer horse-power hour, for the compound freight locomotives tested is, for low speeds, between 2.0 and 3.7 pounds. Results at higher speeds were obtained only from a two-cylinder compound, the efficiency of which under all conditions is shown to be very high. The coal consumption per dynamometer horse-power hour for this locomotive at the higher speed increases from 3.2 to 3.6 pounds.

25. The coal consumption per dynamometer horse-power hour, for the four compound passenger locomotives tested, varies from 2.2 to more than 5 pounds per hour, depending upon the running conditions. In the case of all of these locomotives, the consumption increases rapidly as the speed is increased.

26. A comparison of the performance of the compound freight locomotives with that of the simple freight locomotives is very favorable to the compounds. For a given amount of power at the drawbar, the poorest compound shows a saving in coal over the best simple which will average above ten per cent, while the best compound shows a saving over the poorest simple which is not far from forty per cent. It should be remembered, however, that the conditions of the tests, which provide for the continuous operation of the locomotives at constant speed and load throughout the period covered by the observations, are all favorable to the compound.

27. It is a fact of more than ordinary significance that a steam locomotive is capable of delivering a horse-power at the drawbar upon the consumption of but a trifle more than two pounds of coal per hour. This fact gives the locomotives high rank as a steam-power plant.

28. It is worthy of mention that the coal consumption per horse-power hour developed at the drawbar by the different locomotives tested presents marked differences. Some of these are easily explained from a consideration of the characteristics of the locomotives involved. Where the data are not sufficient to permit the assignment of a definite cause, there can be no doubt but that an extension of the study already made will serve to reveal it.

F. H. CLARK, Chairman,
C. H. QUEREAU,
H. H. VAUGHAN,
Committee.

CHICAGO, ILL., May 5, 1906.

MR. F. H. CLARK (C. B. & Q.): The committee has completed the work for which it was appointed, and having rendered its report to the Association, ask to be discharged. [Applause.]

MR. G. R. HENDERSON: Mr. President, I move that the report be received with thanks and the committee dismissed. I would also like to add to that, Mr. President, that the Committee on Resolutions be instructed to prepare a memorial to the Pennsylvania Railroad expressing our appreciation of the work accomplished. (The motion was carried.)

MR. J. F. WALSH (C. & O.): Mr. President, the report is so complete and comes from a committee of such able men that it does not seem to me as though there was any room left for discussion, and I would suggest that we pass on to the next subject.

THE PRESIDENT: A motion that the discussion be closed will be in order.

C. H. QUEREAU (N. Y. C.): Before that motion is put, Mr. President, I would like to offer a suggestion. Those of you who have read the report or listened to it as presented by the committee of this Association, realize that a great deal has been omitted in this report, necessarily, compared with the original report. I have had a great many inquiries from people who were interested, for the detailed report. The Pennsylvania people published only 1,000 copies. I am inclined to believe that that number of copies will not be sufficient to meet the wants of those who would like to get the detailed report. I would therefore suggest that the

Executive Committee of this Association communicate with the Pennsylvania Railroad to see if it is possible to obtain the plates of the complete report, and communicate with the Society of Mechanical Engineers to see if it is possible and practicable to publish, for the two associations — the American Railway Master Mechanics' Association and the American Society of Mechanical Engineers — the complete report. Of course, I know nothing as to the disposition of the Pennsylvania Company in this matter. I have no adequate conception of what the cost of such publication would be. But, assuming that we could obtain the plates from the Pennsylvania Railroad, it ought not to be large. I am strongly impressed that it would be a fitting monument of this work and also of sufficient importance to warrant this investigation. I will make a motion to that effect.

MR. WILLARD A. SMITH (*Railway Review*): Mr. President, in regard to Mr. Quereau's suggestion, it seems to me it is a little premature to make such a suggestion to the Pennsylvania Railroad, for this reason — it is understood to be their intention, as soon as the plant is in running order at Altoona, to complete the series of tests which were originally planned, especially those of the simple locomotive. Those tests would form a very necessary and very valuable part of the entire report. I am not informed to what extent they intend to make public the results of those tests, but presumably it is their intention, as soon as those tests are completed, to make a full series as originally planned, and to publish a supplement of the report already issued. When that is done, it seems to me that if this association and the American Society of Mechanical Engineers could make such an arrangement as Mr. Quereau has suggested, embracing both series of reports, it would be highly advantageous; or it is possible that these two associations might assume the expense of publishing this supplemental report of the tests that are still to be made, if the Pennsylvania Railroad Company so desires. I say this without any knowledge of their intentions, further than that it is their intention to use the plant as soon as it is in operating order to complete that series of tests.

A motion was made, seconded and carried that the discussion be closed.

THE PRESIDENT: Next in order is the reading of the report of committee on the subject of "Water Softening for Locomotive Use." Is Mr. Carney present? If there are no objections the Secretary will read this report. The report is as follows:

REPORT OF COMMITTEE ON WATER SOFTENING FOR LOCOMOTIVE USE.

To the Members:

At the thirty-eighth annual meeting of the American Railway Master Mechanics' Association your committee outlined its views on the value of water purification, and the subject was continued for the committee to report on the advisability of using a mechanical or other system in connection with a locomotive for the purpose of overcoming the bad effects from the use of undesirable feed-water.

While your committee has expressed itself that the purification of water before delivery to the locomotive boiler is desirable, it also realizes that there may be conditions where the cost of erecting a purifying plant might not be advisable, and that some treatment of water in the boiler is necessary. Whatever the treatment may be, a carefully systematized blowing-off process must be instituted without which no treatment of water in a locomotive boiler can be successful.

The committee gives below a series of reports of the results obtained by treating water, both before feeding it into a locomotive boiler and treating it in the boiler.

No. I.— CONTINUOUS PROCESS:

The following is a brief report of the results obtained by a railroad, purifying water by means of a continuous process. There are ten plants in operation and the following figures give the cost of treatment, together with the results obtained. In connection with the treatment of water is an elaborate system of blowing off and washing with hot water:

	Total gallons pumped.	Pumping, cost per 1,000 gallons, labor, fuel, etc.	Treating, cost per 1,000 gallons, labor, chemicals, etc.	Total per 1,000 gallons.
A*.....	128,900,000	4.00 cents	1.80 cents	5.80 cents
B.....	48,085,000	2.16 "	1.27 "	3.42 "
C.....	38,000,000	2.11 "	1.48 "	3.59 "
D.....	47,360,000	1.3 "	1.18 "	2.48 "
E.....	47,200,000	1.1 "	1.24 "	2.34 "
F.....	200,300,000	0.6 "	1.07 "	1.67 "
G.....	44,690,000	0.7 "	2.03 "	2.73 "
H.....	18,290,000	3.52 "	3.26 "	6.78 "
I.....	28,630,000	2.93 "	2.53 "	5.46 "
K*.....	22,700,000	7.00 "	4.02 "	11.02 "
Total..	624,155,000			

Average cost of pumping, including cost of fuel, labor, etc. (No interest on investment and no allowance for deterioration) per 1,000 gallons.....2.037 cents.

Average cost of treatment, including labor, chemicals, etc. (No interest on investment and no allowance for deterioration) per 1,000 gallons .....1.589 cents.

Total average cost of water per 1,000 gallons pumped, treated and delivered to storage tanks .....3.626 cents.

* Water is purchased at 4 and 7 cents per 1,000 gallons, respectively.

Also please find statement showing the practical results as found from our reports of August, 1902, using untreated water, and November, 1905, when treated water was very generally used, relating to leaking engines and boilers washed.

TRAINS GIVEN UP.

August, 1902 27
November, 1905 .....None.

ENGINES SETTING OFF CARS ACCOUNT OF LEAKING.

August, 1902 13
November, 1905 .....None.

ENGINES CUT OFF THROUGH TRAINS ACCOUNT LEAKING.

August, 1902 45
November, 1905..... 5

ENGINES HAVING TUBES CAULKED.

August, 1902.....803
November, 1905.....469

BOILERS WASHED.

August, 1902.....466
November, 1905.....146

BOILERMAKERS' WAGES.

August, 1902 .....$401.50
November, 1905..... 210.90

BOILERWASHERS' WAGES.

August, 1902 .....$485.00
November, 1905 ..... 399.75

LIFE OF TUBES AUGUST, 1902.

20 by 26 inch cylinder consolidated, 11 to 12 months.
21 by 30 inch cylinder consolidated, 8 to 10 months.

LIFE OF TUBES NOVEMBER, 1905.

20 by 26 inch consolidated.....27½ months.
21 by 26 inch consolidated.....13½ months.

About 10 per cent less engines handled in 1905 than in 1902; 20 by 26 inch engines in somewhat lighter service in 1905 than in 1902. Other engine service the same.

The water is treated for carbonate of lime, sulphate of lime and sulphuric acid by the use of lime and soda ash, applied through the continuous system. The treatment of water causes some boilers to foam; this is taken care of by the water-changing devices which enable the complete discharge of the contents of a boiler containing 2,500 gallons and fill it and have the engine ready for service in thirty-two minutes without dumping the fire.

The report of comparative cost of boiler washing with and without treated water, includes the cost of water changing.

We are not able to show to what extent the life of the fire boxes has been increased, but boxes that were scheduled to be renewed one year ago are in service and doing well. The life of the tubes has been materially increased. The greatest benefit derived from water purification is the ability to keep locomotives in more constant service, with a great reduction of engine failures.

No. II.—INTERMITTENT PROCESS:

The following is a report from a railroad using an intermittent process of water purification:

The water is mixed with chemicals and allowed to flow into a settling tank. After the sediment has settled the water is pumped into service tanks, two or three settling tanks being used at one plant. Through the use of purified water, 35 boilermakers at $10.40 per hour and 42 boilermaker helpers at $7.09 per hour in 1902, have been reduced in 1904 to 23 boilermakers, costing $7.71 per hour, and 35 boilermaker helpers, costing $6.70 per hour. This shows a decrease in the cost of boilermakers of 21.4 per cent and a decrease in boilermakers' force of 56 per cent. The greater proportion of skilled help used in 1905 than in 1902 acccounts for the discrepancy between the saving and cost and reduction of force. The tabulated statement gives the reduction in number of boiler failures through the use of purified water:

	August, 1902, to and including June, 1903.	August, 1903, to and including June, 1904.
Leaky flues	544	99
Leaky fire boxes	33	20
Leaky arch tubes	6	1
Total	583	120

There has been a reduction of 80 per cent in boiler failures in 1903, over 1902 and the reduced number of failures was made with an increased tonnage. In 1902 there were 2,934,930,377 ton-miles handled with 28.7 pounds coal per 100 ton-miles; in 1903, 3,154,484,507 ton-miles were handled with 27.5 pounds coal per 100 ton-miles.

In 1902 159 engines were used and in 1903 154 engines were used with 6.6 per cent increase in ton-miles, with a saving of 4 per cent in the number of engines.

The above figures show that the boilermakers' force was reduced 56 per cent, the cost of boilermakers 21.4 per cent, engine failures decreased 80 per cent and the tonnage increased 6.6 per cent, with a decrease of number of engines used of 4 per cent.

It is difficult to say to what extent the cost of labor and material for maintaining engines had been effected by purified water, but it is safe to say that a material decrease has been effected in this direction. Engines that formerly had their flues reset and heavy repairs to fire boxes, are now taken in for repairs to machinery and resetting a portion of the flues only, and from six to eight months' additional service is obtained.

The benefits to be derived and which can not be computed in dollars and cents, are the short time required for engines on the road, due to tight boilers, the better feeling among the men and longer time at terminals, which not only gives time to keep the engines in better condition, but makes a greater saving in coal due to shorter hours on the road and less overtime paid to engine and train crews.

Engines which ordinarily would be held in for emergency relief calls, are now sent out in regular service, so that a better distribution of power can be made. These items are very difficult to reduce to dollars and cents value, but they mean an immense saving.

No. III.— MECHANICAL PROCESS:

The following is a report from a railroad using a process for purifying water after it is fed into the boiler:

The device used consists of a system of perforated pipes and blow-off cocks. The water is purified by a special oil introduced into the boiler. The success of this device depends upon absolutely living up to the blowing-out instructions. The results obtained are as follows:

First — Decrease in the times locomotives have their boilers washed which amounts to ..... 83 per cent.

Second — Increase in service of flues between resetting of ..... 24.82 per cent.

Third — Increase in average mileage per engine between engine failures ..... 147 per cent.

Fourth — Increase in mileage of engines between resetting and removing of flues of ..... 7.35 per cent.

The fire boxes are kept comparatively free from scale, which reduces the amount of boiler work necessary and increases the life of fire box. This system of purification shows a decrease in the cost of operation of $1,323.03, or equal to 41.7 per cent. For less number of times boiler washing, has been calculated on $15 per day for engine and for the period of one month will amount to $2,025. The saving in wear and tear to machinery is estimated at $25 per engine per year, and amounts to $400. These figures added to the decrease of operation, $1,323.03, will make the total saving for one month of $3,748.03, or a saving for a period of one year of $44,976.36.

Below is detailed statement of above figures:

	Chemical Treatment.	Mechanical Treatment with Oil.
Number of times boilers washed	1,117	192
Cost of operating chemical plant	$ 454.29	.....
Cost of washing boilers	2,721.51	$ 490.77
Cost oil used in oil treatment	.....	1,362.00
	$3,175.80	$1,852.77
Decrease in cost	.....	1,323.03
Percent in decrease in cost	.....	41.7%

In addition to the above, the following estimated saving is effected:

Saving in time due to washing 925 additional times at 3 hours and 30 minutes each, equals 130 days at $15 per day for engine hire $2,025.00

Saving in wear on machinery per month on the basis of $25 per engine per year, cylinder and valve work only 400.00

Total saving $3,748.03

Per cent. of saving ..... 118 per cent.

Plus no engines with mechanical devices washed once a month.

Engines when using chemically treated, washed on an average of every five days.

NOTE.— As shown, the above performance is based on washing engine once a month, and while this can be done, conditions must be favorable. There are, however, times when conditions are such that require washing of engine twice monthly and in these cases we would arrive at the following figures:

	Chemical Treatment.	Mechanical Treatment.
Cost of operating chemical plant.....	$ 454.29	.....
Cost of washing boilers.....	2,721.51	$ 981.54
Cost of oil used in oil treatment.....	.....	1,362.90
	$3,175.80	$2,344.44
Decrease in cost	.....	831.36
Per cent saving.....	.....	26%

No. IV.— CONTINUOUS AND INTERMITTENT PROCESS:

This railroad is using a number of different devices for water purification. The continuous process and the intermittent process of treatment before the water is fed to the boiler and also treatment in the boiler.

On 206 miles of main line there are five water stations furnishing purified water, four of them being continuous process and one intermittent.

The flue failures causing a delay of more than five minutes on the divisions using this water have decreased as per following table, which includes freight and passenger:

Year.	No. Failures.
1901	805
1902	395
1903	332
1904	169
1905	135

NOTE.—No purified water in 1901, part purified in 1902-1903, and all water supply purified in 1904-1905.

During 1904, 1905 and for the four months in 1906, there have been no delays to passenger trains on the 206 miles using purified water, on account of leaky flues.

One division has been equipped for feeding from two to five grains per gallon to the suction pipe of the pump delivering the water to the supply tubs. The record of flue failures for thirteen months is as follows:

Year.	1905	1905	1905	1905	1905	1905	1905	1905	1905	1905	1905	1905	1906
Month. ..	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
Failures .	11	18	1	1	1	3	4	1	1	1	0	0	0

Engines using this treated water are equipped with a single perforated blow-off pipe in the back water leg of the fire box. It has been found that the mud works toward the back water leg and frequent systematic blowing off will keep the mud down to a minimum.

The following statement shows the saving made, due to treatment as above outlined:

FAILURES DUE TO LEAKY FLUES.

	No. Failures	Total Mileage.	Miles per Failure.
Nov. and Dec., 1904, and Jan., 1905....	27	567,115	21,004
Nov. and Dec., 1905, and Jan., 1906....	1	605,196	605,196

	Staybolts Replaced.	No. Men in Roundhouse.
Nov. and Dec., 1904, and Jan., 1905....	498	5 boilermakers. 2 helpers.
Nov. and Dec., 1905, and Jan., 1906....	103	2 boilermakers. 2 helpers.

	Boilers Washed.	
	No. Times Washed.	Miles per Washing.
Nov. and Dec., 1904, and Jan., 1905.....	389	1,432
Nov. and Dec., 1905, and Jan., 1906.....	325	1,862
January, 1905	107	1,620
January, 1906	63	3,175

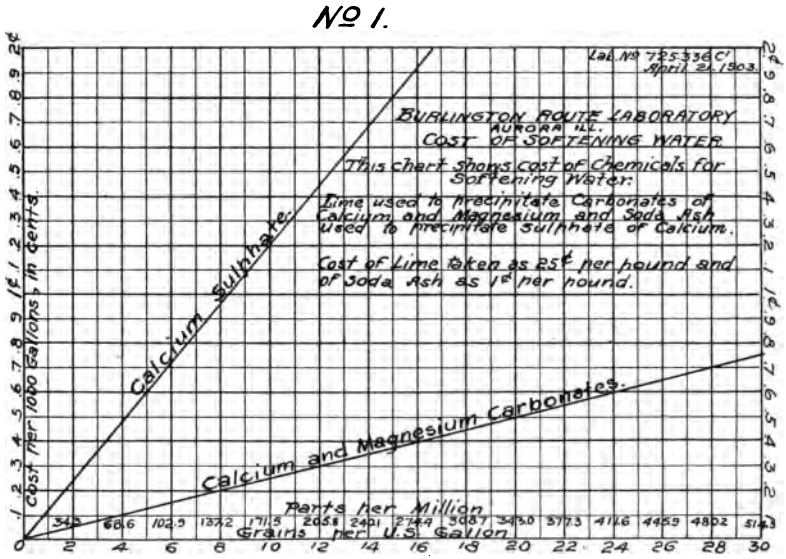
Engine 1718 ran from January 1, 1906, to February 8, 1906, as an experiment, and made 5,100 miles, and when opened up for washing, no more mud was found on the mud ring than in an engine which had made considerably less mileage.

Switch engine 1426, built new December 27, 1902, in constant service twenty-four hours per day, commenced to use water treated by intermittent system in April, 1904; engine was given a general overhauling April 17, 1905, and no flues removed. It came into shop for a second overhauling February 10, 1906; flues were removed for inspection and it was found that they were barely coated with a fine powder which could be brushed off the iron. This switch engine was washed out every thirty days.

Consolidation engine No. 3164, in pusher service twenty-four hours per day, had flues reset September, 1904; the engine came in for general

overhauling November, 1905, and the flues were removed. It was found that there was practically no scale on any of the flues or accumulation of mud or scale in any part of the boiler. This engine had been using purified water exclusively and the flues were removed for inspection. Both this engine and the switch engine mentioned above were blown out twice a day.

The cost of treatment for chemicals is shown in diagram No. 1. Lime quoted at ¼ cent per pound, and soda ash at 1 cent per pound.


No 1.
Lab. No 725336 C'
April 21 1903.
BURLINGTON ROUTE LABORATORY
AURORA ILL.
COST OF SOFTENING WATER.
This chart shows cost of Chemicals for Softening Water:
Lime used to precipitate Carbonates of Calcium and Magnesium and Soda Ash Used to precipitate Sulphate of Calcium.
Cost of Lime taken as 25¢ per pound and of Soda Ash as 1¢ per pound.
Calcium Sulphate.
Calcium and Magnesium Carbonates.
Cost per 1000 Gallons in Cents.
Parts per Million
34.5 68.6 102.9 137.2 171.5 205.8 240.1 274.4 308.7 343.0 377.3 411.6 445.9 480.2 514.5
Grains per U.S. Gallon
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

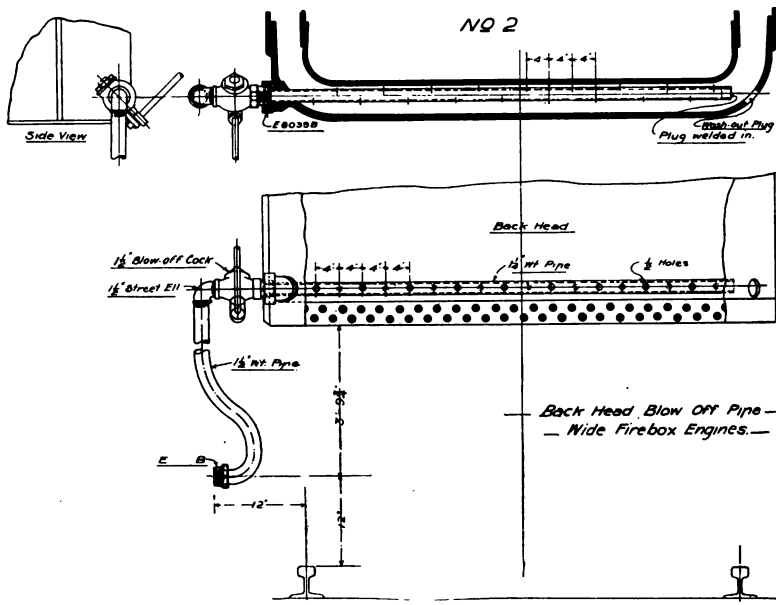
It is difficult to determine how much scale-forming matter should be contained in a water before purification is necessary. The most approved method of water treatment does not remove all of the scale-forming material and it would be useless to treat waters so low in incrustating solids that they approached the quantity which the purifying process failed to remove.

Waters containing over three grains of calcium sulphate or magnesium carbonate, whether there is other scale-forming material or not, should be treated. The treatment will not remove all of the scale-forming matter, but will convert the sulphate into carbonate, which produces scale to a much less degree than does calcium sulphate. Water containing over six grains of total incrustating solids, a part of which is sulphate, should be treated. Water containing eight grains of incrustating solids, all of which are carbonate, should be treated. Any trace of free acid should be neutralized before the water is fed into the boiler.

There is no known method of treatment for alkali, and the only way to overcome its bad effects is to blow out the boiler systematically and

thereby prevent the concentration of alkali, which will produce foaming. Systematic blowing off is necessary in any method of treatment and will do great good, even if no purifier is used.

An arrangement of perforated blow-off pipe placed at the bottom of the back water leg of a fire box is shown on diagram No. 2. This



arrangement has been used on the C. B. & Q. R. R. for some time and has given most excellent results, keeping the boiler as free from mud as a much more complicated system of blow-off cocks would accomplish. A floating outlet pipe in the supply tank will be found of great benefit with muddy water, whether purified or not.

Your committee is indebted to Mr. C. M. Davidson, Chemist and Engineer of Tests of C. & N.-W. Ry., and Mr. M. H. Wickhorst, Engineer of Tests, C. B. & Q. R. R., for information, method of treatment and results.

J. A. CARNEY, Chairman,
L. H. TURNER,
R. QUAYLE,
C. E. FULLER,
J. F. DUNN,
J. G. NEUFFER,
Committee.

W. BURLINGTON, IOWA, May 10, 1906.

THE SECRETARY: I might say that Mr. Fuller, one of the members of the committee, is present this morning, also Mr. Neuffer.

THE PRESIDENT: You have heard the reading of the report. What disposition shall be made of it?

MR. G. R. HENDERSON (New York): I move that the report be received and opened for discussion. (Seconded and carried.)

THE PRESIDENT: It is now open for discussion.

MR. G. R. HENDERSON: I would like to call attention to the second paragraph on page 9, which states that there is no known method for the treatment of alkali. That is true probably in the sense of treatment, but I believe it is perfectly feasible under certain conditions to purify alkali water by distillation. There are distilling apparatus which will give you anywhere from thirty to sixty pounds of water per pound of coal, and with coal at a basis of $1 per ton (it can be had for very much less on a great many of the railroads in the western part of the country) it is possible to distill water at a cost of approximately 10 to 12 cents a thousand gallons; and while that is considerably higher than the cost of chemical treatment, yet I think that any one who has experienced the great troubles of alkali water from foaming would consider it a good investment. I would like simply to call attention to the fact that alkali water can be treated in such a way if people will go to the necessary care and expense. I have made some preliminary experiments myself and found that it could be done for about the cost that I have stated — 10 or 12 cents a thousand gallons.

MR. C. E. FULLER (C. & A.): The report of the committee as to paragraph No. 3 is not covered by a purifying plant; it is simply the treating of the water in the boiler by the use of an oil, which prevents the formation of scale on the boiler plates, and the water in the boiler foaming.

MR. A. E. MITCHELL: I would like to hear Mr. Fuller tell us some of the results he is obtaining on the Alton road with his boilers. I understand he has had remarkable success with the mechanical system and I think it would be well to have him give us some information.

MR. C. E. FULLER (C. & A.): In reply to Mr. Mitchell's inquiry.— About 1900 the Alton took up the question of the purification of water by the treating plant system. On account of it not being entirely satisfactory on account of engines foaming badly, which interfered with the successful hauling of trains, and owing to the fact that it was necessary to wash the boilers or change the water practically at the end of each round trip, my predecessors went into the system of an oil device known as the Talmage system. When I became connected with the Alton road I found they were still using the treating system and, in addition, the oil system. Both of these systems are expensive luxuries if not entirely unnecessary for the successful operation of locomotives, but with the nature of the water that is on the line of our road, especially at Bloomington, it seemed absolutely necessary to do something to prevent the formation of scale and stop the continual boiler failures. The subject had been gone over for some time very carefully and the results watched. Some of the engines equipped with the oil device were put in the districts where the water was bad and no treated water used; others were kept in a district using treated water, and, in addition, the oil treatment, and from the results obtained it was decided that it was not necessary to treat water and, in addition, use the oil, and that we were getting better results with the use of the oil only, and it was finally decided to abandon one or the other. After making a thorough and careful investigation of the results obtained with the use of oil, and the results from the treated water, and taking into consideration the cost of same, it was finally decided to stop the treating of the water and adopt the use of the oil, which was done along about February, 1904. Since that time we have used nothing but oil in our boilers to prevent the formation of scale. We have practically all our heavy capacity engines, from 19-inch cylinder up, equipped with this device. We found, by using the oil and abandoning the treating of our Bloomington water with soda ash and lime, that we have entirely eliminated the foaming of the water in our boilers and we are able to keep our fire-box sheets practically free from scale, which has materially extended the life of our fire boxes, as well as the flues. It has also enabled us to run our locomotives from

fifteen to thirty days between boiler washings and without changing the water, where, under the treating system, it was generally necessary to wash the boilers or change the water at the end of each round trip.

The oil system that we have in use requires a good deal of attention and continual vigilance, and to obtain successful results it is imperative that the oil should be used regularly and that the blow-off cocks should be properly and thoroughly operated at the end of each trip, blowing out all the sediment that collects in the boiler and around the mud ring. Where you can rely upon your enginemen to operate the blow-off cocks at stated intervals, on the line of road, still better service is obtained, but we have not compelled our enginemen to do this, but have made the matter a mechanical question and hold our terminals responsible for properly operating the blow-off cocks.

The results have been so gratifying that in the year 1904 we brought about a decrease in tonnage set out of trains, due to engines foaming, as compared with the year 1903, of about 38 per cent, for the same class of engines in the same territory. We do not know what it is to have an engine reported as foaming, and we have so materially reduced our engine failures, due to fire box, flue leakages and foaming, which were the greatest source of trouble and annoyance, that upon making comparison with the performance of engines prior to being equipped with this system, our engines show an increase at present time, in average mileage per engine between engine failures, of 147 per cent, and an increase in the service of flues between resetting of 24.82 per cent.

We, so far, have no reason to regret the step taken in adopting this system, and would say for the benefit of the members of this Association that there was no one any more opposed to this device than I was, as I did not believe the results could be obtained. I believe it would pay any member, who is having trouble with bad water, to carefully investigate this manner of taking care of bad water and find out for themselves just what the results are. Your water and your results may not agree with ours, as I am only speaking of the results obtained with the class of water that we use.

MR. G. R. HENDERSON: I would like to ask Mr. Fuller two points: One, what are the ingredients in the water to which he refers where this oil has been successfully used, and another, whether there has been any appearance of blisters or pockets on the fire boxes, or other parts of the sheets. We know that in stationary plants in the East they are very particular about allowing no oil from the cylinders to get into the boilers, and they practically throw enormous amounts of money away every year in waste water and heat so as to prevent oil from getting into the boiler. There are different kinds of oils, but I would like to have it made clear whether there is any appearance of that trouble, and also what are the ingredients in the water.

MR. C. E. FULLER (C. & A.): I had forgotten that point and am very glad you called my attention to it. When we went into the oil treatment the statement was made to us that in using oil in a boiler it would collect on the flues and side sheets, that it would prevent the heat passing through the sheets and that the residue contained in the oil would cause trouble; in fact, we became very much alarmed in regard to the ultimate results, and to prove conclusively whether or not there was any truth in the information that was given us, we started the use of this oil very systematically in our stationary boiler plant at Bloomington, where we use nothing but bad water, and where we could constantly watch the results and condition of the interior of the boilers, the boilers being of the Stirling type, 350 horse-power. The water we use contains from 42 to 45 grains of solids.

MR. HENDERSON: What is the solid?

MR. FULLER: The principal solids in this water are about 15 grains of calcium sulphate; about 10 grains of calcium carbonate, and about 10 grains of magnesium carbonate. As you all know, in a Stirling boiler the circulation in the back tubes is very sluggish, which resulted in the solids collecting in the back tubes. We have run the Stirling boiler, with this device, practically eighteen months with the best of results and we have been able to reduce the time required to bore the flues in one battery of boilers from ten and one-half days, working day and night shift, to twenty-four hours. We find that in place of scale forming in these boilers from one-quarter to three-eighths inch in thick-

ness in thirty days, with the use of the oil it now forms less than a sixteenth. We have never removed a flue from one of these boilers on account of the same being blistered. There is no foaming of the boiler with the use of this oil and we have so far found absolutely nothing to indicate any signs of pitting or blistering, but, to the contrary, the interior of our boilers shows a very healthy condition. From the length of time that this system has been in use we feel absolutely sure that there is nothing in the oil that will in any way damage the interior of a boiler. The oil apparently does not remain on the sheets, but mixes with the water.

Since we have abandoned the system of treating water with soda ash and lime and adopted the use of the oil in our locomotives, it is a very rare case where we find it necessary to bore a cylinder, bore out a valve bushing, or face a valve. Up to about 1904 our roundhouses were practically workshops for removing pistons, applying packing rings, facing valves, removing valve bushings, etc. There is no question in our mind but what the oil has its beneficial effect and that the steam is more or less saturated with this oil. We have not changed our mixture of metal and are using cylinders and valves of the same mixture of cast-iron as in the past. We make these castings ourselves, therefore we know what the mixture is.

I think I have answered Mr. Mitchell's question, but if any one wants to ask any further questions I will be very glad to answer them to the best of my ability.

MR. WILLIAM FORSYTH (*Railway Age*): After such a strong statement in regard to the oil treatment as compared with the chemical treatment, I think it would be proper for Mr. Fuller to explain whether the chemical treatment on his road was properly conducted and whether the chemicals used were correct.

MR. C. E. FULLER (C. & A.): We had a chemical plant known as the Wefugo Plant. The objection to it was that we could not mix the lime and soda ash in such proportion as to give us a good boiler water and at the same time not foam. We could, however, with this treating plant, prevent the formation of scale to a large extent, but on account of our engines foaming so badly it interfered with the successful operation of the engines.

The water changed its conditions continually so that it was necessary for us to change the proportion of lime and soda ash accordingly. We also found another difficulty, and that was in the quality and grade of lime. As soon as the lime began to slack it had a different effect in its use and we found it necessary to continually analyze the water and change the proportions, but with all this we did not get what we felt were good results. We found that after a locomotive left Bloomington with a tender full of treated water and at the next station took water that was not treated, the results were not satisfactory and it was a serious question with us whether we would not have to treat all our waters so they would harmonize one with the other. We had any quantity of engine failures caused by mixing untreated water with treated water.

MR. D. J. DURRELL (Penna. Lines West): The last point brought up by Mr. Fuller in regard to the neutralizing of the waters, whether one plant was installed or several, has come up with us and we find we have just the opposite results from what Mr. Fuller states. For the past three years we have been using purified water on some of our divisions, and we found by installing one plant on one division that it so neutralized the water taken not only at adjacent water tanks to the purifying plant, but at far water tanks, sufficiently to help us out of our trouble. On this one division I speak of we had at one time twenty-seven new 8-6-A consolidated locomotives. When they first came on the road we were troubled with a great deal of cracked fire-box sheets. By installing this purifying plant we eliminated the trouble absolutely. Whether it was by reason of purifying the water or not, I do not know. I do not want to put myself on record as saying that that stopped the trouble, but the trouble stopped. We find that the water changes in rivers or streams but not in deep wells. As to the point made by Mr. Fuller, we met that by changing the daily charge of chemicals, the lime or soda ash, to correspond with the hardness of the water in the streams as it changed with rains or dry seasons. We have reduced our roundhouse work at some points 25 per cent, at other places 45 per cent by the use of purified water. With us it has gone far beyond the experimental stage. We have three plants in opera-

tion, another one being erected which will be in operation within the next thirty days, and we expect to install probably two or three others in the very near future. I think it is a subject that everyone should learn all they can about, and I am satisfied that there will be reduced engine failures, reduced roundhouse expenses, and that there is nothing that will help out as much as the purification of water.

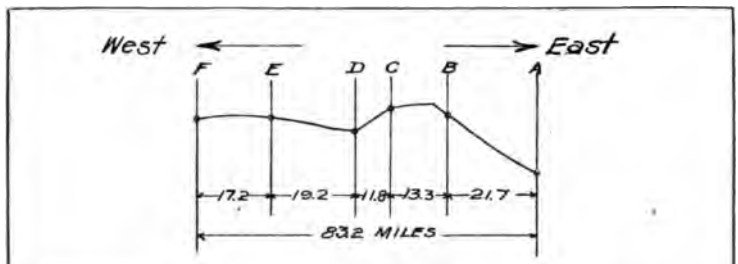
MR. G. W. WEST (N. Y. O. & W.): We have only one bad water station on a division of 100 miles, and we have installed a water-softening plant. It doubled the life of our flues and certainly reduced the roundhouse work repairs on the flues to that extent. Our experience is similar to that of Mr. Durrell, that we find no bad results in mixing the water.

MR. WM. MCINTOSH (C. R. R. of N. J.): We have one purifying plant installed at Elizabethport, N. J., and for awhile obtained very good results from it. We, however, had arrangements made that piped the rain water into a cistern and it mixed there with the untreated water. We expected to control this by reducing the quantities of chemicals when there was a large quantity of rain water, but have not succeeded in reaching the proper combination. We also have found some changes taking place in the quality of water that we pumped from the wells. To illustrate the necessity and importance of handling a purifying plant intelligently we have recently discovered that through either negligence on the part of those in charge, or some chemical change taking place, we were adding twelve grains more solid matter to the water than it contained in its original state, and are now trying to find out where we are at. No doubt indifference and ignorance will account for a purifying plant failing to accomplish good results.

MR. C. E. FULLER (C. & A.): I would like to ask Mr. Durrell if he does not find it necessary to continually change the proportions of soda ash and lime in treating his water, and if he employs a chemist who makes a daily analysis of the water. This is a matter which I think should come to the notice of everybody interested in this subject, as we found it absolutely necessary, with a treating plant, to continually analyze the water before and

after treating, due to the analysis of the water changing and the grade of lime used.

MR. D. J. DURRELL (Penna. Lines West): As previously stated, we have one district of one division 83.2 miles long; on this district we had six water stations, and to make the matter more clear I attach a drawing showing the total length of district, location of each water station, A, B, C, D, E and F, and the distance between each station; also the source of supply, whether from stream, pond or well, the amount of water purified daily and the chemical analysis of the waters at the various stations. Particular attention is called to the incrusting or scale-making solids in the various waters, and especially to the grains



÷ ANALYSES OF WATER ÷

	A.	B		C	D	E	F
		TREATED	UNTREATED				
SOURCE OF SUPPLY	CREEK	CREEK		LAKE	MILL POND	CREEK WELL	CREEK
AMOUNT OF WATER PUMPED DAILY, 1000 GAL. UNITS	4488	92.5		5.0	34.0	75.5	184.4
CALIUM CARBONATE	15.21	2.55	7.15	9.60	12.75	12.00	16.20
" SULPHATE	3.17	0.0	0.0	0.0	0.0	0.0	0.0
" CHLORIDE	0.28	0.0	0.0	0.0	0.0	0.0	0.0
MAGNESIUM CARBONATE	2.07	1.22	1.39	1.18	4.79	5.63	3.49
" SULPHATE	9.30	0.0	3.18	5.16	2.28	1.92	7.50
" CHLORIDE	0.0	0.0	0.29	0.0	0.48	0.0	0.0
SODIUM SULPHATE	3.12	3.85	0.0	1.21	0.0	3.41	0.0
" CHLORIDE	1.46	0.88	0.53	0.59	0.29	0.59	0.29
" CARBONATE	0.0	2.60	0.0	0.0	0.0	0.0	0.0
IRON AND ALUMINA	0.0	0.01	0.19	0.28	0.10	0.22	0.35
CARBONIC ACID	1.35	0.0	0.88	5.40	5.10	4.32	4.63
SILICA	0.59	0.20	0.60	1.54	0.98	0.94	0.73
ALKALINITY	22.2	4.81	9.28	11.66	19.53	19.82	21.57
SUSPENDED MATTER	0.93	3.50	1.28	0.29	TRACES	0.74	1.41
INCRUSTING SOLIDS	31.55	2.76	21.18	18.05	21.38	21.45	29.88
NON-INCRUTING SOLIDS	4.58			1.80	0.29	4.00	1.70
HARDNESS		4.22	11.96				

of incrusting solids, per U. S. gallon, in waters at **stations A and** F. One water-purifying plant was installed at station **B, and the**

results of the purifying of this water is given in the second column of the figures, from which it will be seen that the grains per U. S. gallon were reduced from 21.18 to 2.76. On this district

REPORT OF STATION "B" FOR THE WEEK ENDING JUNE 9, 1906.

Date.	Gallons Pumped.	Raw Water.		Chemical Charges.				Treated Water.			
				Soda.		Lime.					
		Hardness.	Alkalinity.	Lbs.	Time of Charge.	Lbs.	Time of Charge.	Hardness.	Alkalinity.	Lime Water	Time of Test.
3d	Day, 81,000	53	28	180	7 A.M.	200	7 A.M.	8	13	Good	7 A.M.
	Night, 91,800	55	30	.....	.....	165	5 P.M.	8	13	Good	5 P.M.
4th.	Day, 81,000	55	30	210	7 A.M.	135	7 A.M.	6	10	Good	7 A.M.
	Night, 59,400	56	30	.....	.....	147	5 P.M.	8	13	Good	5 P.M.
5th.	Day, 91,800	56	30	150	7 A.M.	186	7 A.M.	7½	12	Good	7 A.M.
	Night, 78,300	56	30	.....	.....	169	5 P.M.	7½	13	Good	5 P.M.
6th.	Day, 70,200	56	30	.....	.....	125	7 A.M.	9	13	Good	7 A.M.
	Night, 48,600	56	30	.....	.....	135	5 P.M.	6	10	Good	5 P.M.
7th.	Day, 59,400	56	30	190	7 A.M.	174	7 A.M.	8	11	Good	7 A.M.
	Night, 78,300	56	30	.....	.....	100	5 P.M.	10	14	Good	5 P.M.
8th.	Day, 81,000	56	30	.....	.....	152	7 A.M.	8	13	Good	7 A.M.
	Night, 62,100	56	30	.....	.....	170	5 P.M.	7½	13	Good	5 P.M.
9th.	Day, 89,100	56	30	210	7 A.M.	100	7 A.M.	7	10	Good	7 A.M.
	Night, 75,600	57	30	.....	.....	160	5 P.M.	9	14	Good	5 P.M.

sixty-six per cent of new freight power, just prior to the installation of the purifying plant at B, had cracked fire-box sheets, but immediately upon beginning the use of this purified water all this trouble ceased absolutely, and for two years no further sheets have cracked, nor have we had any delays on the district from leaky flues or kindred causes, and all engines are hauling their maximum rated tonnage. We attribute the results obtained, which are highly satisfactory, to the use of this purified water, and the neutralizing of water taken at other stations, by being mixed with the water taken at station B. Since the installation of the plant at B, another plant has been installed at F, which has resulted in better performance on divisions (two) running west from F.

In regard to the employment of a chemist; up to the present time it has not been found necessary to do so. Each morning and evening the station agent at B, who has direct charge of the

plant, determines the degree of hardness in the water (see copy of report for week ending June 9) and instructs the pumper as to the proper charge of lime and soda ash necessary for the day or charge. Ultimately, when we have a number of plants in operation it is proposed to have a man connected with the Motive Power Department take general supervision of all water-purifying plants and follow up the operation and maintenance of same, also to make frequent chemical analysis of the various waters, but at the present time our needs have not required the services of such a man.

MR. G. W. WILDIN (Erie): Some time before I became connected with the Erie Railroad a number of engines were equipped with the Talmage system for water treating, which is the device just described by Mr. Fuller. One of my predecessors, for some reason not now fully understood, had the device removed from all engines and reverted to the time-honored soda-ash treatment. About July, 1904, we began an experiment with this device on a single engine to determine whether or not it was the system or something else which was at fault that caused its removal. We had such phenomenal results with the experimental engine that we decided to equip all engines on the C. & E. division with the Talmage device instead of water-treating plants. The water in this district, running from Marion, Ohio, to Chicago, is very bad, containing as high as sixty grains of incrusting solids per gallon, considerable of which are sulphates. Our decision to use the Talmage system instead of water-treating plants was based on a number of factors which entered into the proposition. First, because of the good results we obtained with the single engine on trial, and second, because we could equip our engines operating in the territory just mentioned for an initial outlay of about $15,000, using the Talmage device, while the first cost to install water-treating plants would have amounted to about $95,000; also, while in general the cost per thousand gallons treated is about the same or a little less with the Talmage system than with water-treating plants, as regards particular tanks of very bad sulphate water, it is very much less.

The flues in the engines equipped with the Talmage system have given us no trouble whatever, and where we formerly

removed and reset them every six months, we are now getting a full term of service from them, which is between shoppings. With reference to the point made by Mr. Fuller as to the benefit to the machinery through the use of Rubra oil in the boiler, I presume most of you have had more or less experience with the maintenance of the Vauclain four-cylinder compound and know the trouble usually experienced in maintaining the pistons in same, especially in bad water districts where there is more or less trouble from boilers foaming. In our experience it was found necessary to renew the pistons about every two and one-half to three months. The engine used in the experiments with the Talmage system had been in service something over a year when it came in the shop for general repairs. I personally calipered the piston heads and, to my surprise, they were found to be within ⅛ inch of their original diameter, which results are, beyond doubt, remarkable.

As far as foaming is concerned, I want to say this, that the Talmage system will positively prevent foaming. I have ridden an engine so equipped which was operating in a bad water district, and which had not been washed out within thirty-six days, and it was impossible to work the engine hard enough to cause foaming. There is another point that might be better explained, that is, the possible settling of the oil in the cylindrical portion of the boiler. Rubra oil is more or less volatile, and a considerable portion passes over with the steam, as evidenced by the good lubrication had, and in this way lessens the quantity that might be supposed to settle to the bottom. This fact, together with the thorough blowing-off which is a part of the system, completes the job.

MR. A. E. MITCHELL: When I was with the Erie Railroad, several years ago, the territory mentioned by Mr. Wildin had the worst water that I ever had any experience with. We were washing the boilers every third round trip, and we tried every boiler compound we could find in our endeavor to do away with the trouble in that respect. Finally the Talmage system was suggested and I was the first man to put that on the Erie, and in order to demonstrate what was in it, we had a man follow the engine all the time. In fact, there was a man on that engine for eighteen months to feed the oil into the boiler properly to see

what results we could obtain. With the Talmage system we doubled the life of the flues. We increased the period of the washings from once in three days to once a month; in fact we thought enough of the device to equip several engines with it, which Mr. Wildin mentioned were taken off by my successor.

MR. G. W. WILDIN (Erie): I want to say one word more concerning the results we are getting with the Talmage system, and that is we are now washing boilers every twenty days, where we formerly washed them every five days. I believe we should, in selecting a system for treating water, select one that can take care of any kind of water, and not be limited to waters of a particular chemical analysis.

MR. P. MAHER (T. St. L. & W.): I wish to ask a question as to the cost per engine, or per thousand miles, by the use of the Talmage system. Nothing has been said about the cost of the use of this system.

MR. C. E. FULLER (C. & A.): It depends entirely upon the condition of your water, the quantity of oil you find it necessary to use. On our worst water district, which is the Eastern Division of 126 miles, we find that it is not necessary to use over a gallon of oil. On our Western Division we run as low as three-fourths of a gallon of oil for 150 miles. As the cost depends entirely upon the number of miles you can run per gallon of oil, the cost can only be determined by your water conditions. The oil is fed into the boiler by a lubricator which is attached to the boiler and operates similar to the cylinder lubricator. The lubricators are filled by roundhouse employees and the amount of oil they put on an engine is governed entirely by the territory in which the engine is to run.

MR. J. F. WALSH (C. & O.): In connection with this matter we have had some very satisfactory experience with our water purification. On our Loup's Creek branch, which runs into one of the most important coal districts, we take our water from Loup's Creek, and all the drainage from the coal mines enters into Loup's Creek. There was a period during low water in the creek, for six or eight weeks, when we were almost at a standstill. We installed a water-purification plant at a point where most of

the engines take water, and it has virtually eliminated all the boiler troubles.

Another thing I might add that has proved very valuable to us in the way of boiler conditions has been the installation of a hot water boiler-washing system, which I think should be mentioned, as long as we have this matter up, That, in itself, has done an immeasurable amount of good in our service. We installed this hot water boiler-washing and boiler-filling plant in the early part of February, and we have running out of this terminal an average of an engine about every forty-five minutes. After the installation of this plant, up to the close of the winter, we did not have one locomotive fail on account of boiler conditions on the entire two districts covered by this water-heating and hot water boiler-washing plant. At another point on our system we had serious trouble with a local engine there, an engine that was located permanently at that point. We would commonly have to send a boilermaker out to that point to attend to the engine, perhaps two or three times a week. After we had our chemist analyze the water and prescribe for it, we got the water in such condition that we do not have to send the boilermaker out to attend to that engine more than once a month. I make this statement for whatever good there may be in the matter.

THE PRESIDENT: The next in order is the report of the Committee on Locomotive Front Ends. Mr. H. H. Vaughan is chairman of the committee.

REPORT OF COMMITTEE ON LOCOMOTIVE FRONT ENDS.

To the President and Members of the Master Mechanics' Association:

The undersigned, your committee, appointed to "assist in the tests being conducted at Purdue University, Lafayette, Indiana, by the *American Engineer and Railroad Journal*, and to carry on the tests outlined in its report to the convention in 1903" respectfully submits the following:

1. HISTORIC STATEMENT.—The Association, as early as 1890, had appointed a committee to report on the best forms of exhaust nozzles and steam passages. This committee, after making one report, and after being continued for several years, finally gave way to a new committee under the chairmanship of Mr. Robert Quayle, with the result that in 1896 an epoch-making report was presented. The work of this committee settled two

important questions, namely, the action of the exhaust jet and the form and proportions of the exhaust pipes and nozzles.

In 1901, the *American Engineer and Railroad Journal* became the patron of Purdue University for the purpose of advancing an experimental study embracing the form and proportion of locomotive stacks, and invited and secured, as an advisory committee, the assistance of distinguished motive power officials. By virtue of this arrangement an elaborate investigation was planned and completed, with results which were expressed in the form of general equations by the use of which it was assumed that the stack for any engine might be correctly proportioned. The results of this investigation appeared in the columns of the *American Engineer* during the following year. These experiments, however, were made upon an engine having a diameter of boiler of but 52 inches, which is far less than that of the modern locomotive, and they were chiefly concerned with the problem of the outside stack. In consequence of these facts there was a common desire to have the experiments repeated upon a locomotive of large size and to have the study extended to include the draft pipe problem, the effect of inside stacks and of false tops in the smoke arch. In response to this feeling, the Association in June, 1902, laid the foundation for the work which finds its completion in the present report. It was at this time that your committee was appointed. A year later the committee made a report giving a summary of the work already accomplished and presenting an outline of such additional work as was most needed. It reported that Purdue was ready to proceed with the work, that the New York Central Railway Company was prepared to loan an engine of large size for the use of the committee, and they submitted an estimate of the cost of the experiments they proposed. This report was received and the committee continued for another year, since which time it has each year made a report of progress and has been continued. While the committee was ready to proceed with the active work of the tests in the spring of 1904, it found difficulty in securing a locomotive in the busy months of the summer, and during the fall of that year and the following winter the laboratory was committed to other problems. It was, therefore, not until after the convention of 1905 that active work upon the research was undertaken. New York Central Atlantic type locomotive No. 3929 was delivered to the University Laboratory in November, 1905, and continued to occupy the testing laboratory until the following April. During this interval there were obtained the results herein described.

2. Co-operating Influences.—First among those to whom acknowledgment is due, is the *American Engineer and Railroad Journal*, by whose enterprise the original investigation was outlined and by whose efforts substantial progress in its development was achieved. While its formal contribution has long since been submitted, its interest has not failed, and your committee acknowledges with pleasure the assistance which from time to time has been rendered by representatives of this journal. The Standard

2. That the diameter of stack is somewhat affected by the height of the exhaust tip, the diameter for the best results being greater as the nozzle tip is lowered.

3. That, calling d the diameter of the stack at its smallest part, and D the diameter of the front end, the relation between the diameter of stack and front end when the exhaust tip is at the center of the boiler is

$$d = .25D.$$

4. That the diameter of stack must, for best results, be increased .16-inch for each inch that the exhaust tip is below the center line of the boiler; that is, calling h the distance between the center line and the tip,

$$d = .25D + .16h.$$

5. That a variation of an inch or less from the diameters given by the equation will produce no unfavorable results.

In view of the publicity that has been given these statements, it is important to determine the extent to which their truth is affected by the experiments of the present year.

As to the necessity for varying the diameter with the height of stack, the work of the past year is far less elaborate than that of 1903, but two heights of stack having been employed, namely, those of 29 inches and 47 inches respectively. Comparing draft values obtained from stacks of each of these heights under a uniform back pressure of 3.5 pounds (Series 3 and 4, Fig. 10) it appears that the best diameter for the 29-inch stack is 23 inches. The best results from the 47-inch stack were obtained by use of the largest diameter experimented upon (21 inches). Curves plotted through the several points (Series 4, Fig. 10) show this diameter to approach that for the maximum draft, but it does not equal it. The indication is that if a diameter of 23 inches had been employed it would have been found right for the 47-inch height as well as for the 29-inch height. There is in fact nothing in the experiments of the present year to invalidate the conclusion derived from the preceding work. So far as outside stacks are concerned, therefore, the diameter does not need to be varied when the height is changed.

As to the effect upon the proportion of stack resulting from changes in the height of the exhaust tip, it must be noted that the work of the present year has involved one height of tip only and hence gives no information upon this question. The validity of the conclusion already stated, however, has never been called in question and it may be assumed to stand.

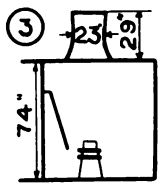
Concerning the actual size of the stack for best results, the work of the present year points to the desirability of using diameters which are somewhat larger than those given by the equation of 1903. This equation is,

$$d = .25D + .16h,$$

which when applied to the N. Y. C. locomotive experimented upon gives

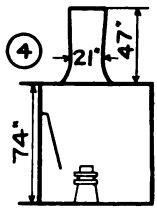
$$d = .25 \times 74 + .16 \times 12.5 = 18.5 + 2.0 = 20.5.$$

whereas, with a stack 29 inches high the best results were actually obtained when the diameter was 23 inches. The difference of 2.5 inches is not great,



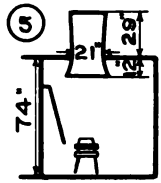
DRAFT, 4.54

FIG. 1.



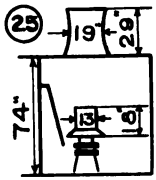
DRAFT, 5.20

FIG. 2



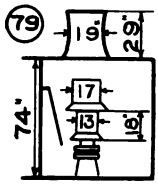
DRAFT, 4.71

FIG. 3.



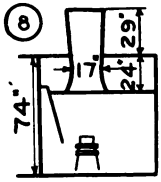
DRAFT, 4.85

FIG. 4.



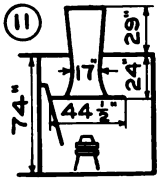
DRAFT, 4.40

FIG. 5.



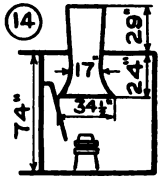
DRAFT, 5.06

FIG. 6



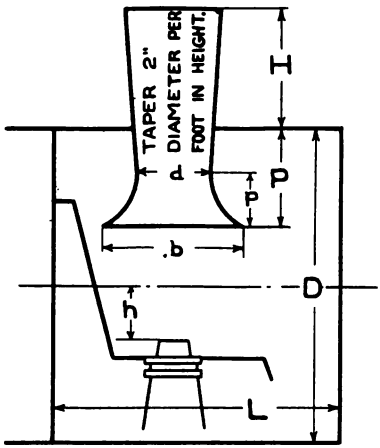
DRAFT, 5.05

FIG. 7.



DRAFT, 4.98

FIG. 8.



BEST ARRANGEMENT OF FRONT END.

FIG. 9.

2. That the diameter of stack is somewhat affected by the height of the exhaust tip, the diameter for the best results being greater as the nozzle tip is lowered.

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which when applied to the N. Y. C. locomotive experimented upon gives

$$d = .25 \times 74 + .16 \times 12.5 = 18.5 + 2.0 = 20.5.$$

whereas, with a stack 29 inches high the best results were actually obtained when the diameter was 23 inches. The difference of 2.5 inches is not great,

especially in view of the fact that it has been distinctly noted that variation of an inch or even more is not important. The difference is to be accounted for also by the fact that in reviewing the results of 1903 there was a common feeling on the part of the members of the advisory committee that the experiments pointed to dimensions which, for service conditions, were excessive. Because of this view, the equation was framed as a conservative expression of the experimental results. The data obtained during the present year might, for like reasons, be similarly treated, in which case the discrepancy of 2.5 inches would be diminished or even be eliminated. Since, therefore, the only element of doubt concerning the results of 1903 has found expression in beliefs that they gave diameters which were too large, it is the feeling of your committee that the work of the present year may be accepted as a full confirmation of the earlier work.

Having shown the value of the work of the present year in confirming the conclusions of 1903, it remains to consider those phases of the present year's work which are to be regarded as extending beyond the scope of the earlier investigations; the effect of which necessarily diminishes the importance of that which has preceded. It will be shown that, however well the plain outside stack may be proportioned, the demands of service require it to give way to a more highly articulated device.

5. INSIDE STACKS.—The experiments included inside stacks of four different diameters ranging from 15 inches to 21 inches, a constant outside height of 29 inches and a penetration into the smoke box of 12 inches, 24 inches and 36 inches, respectively. The best proportions of this form of stack are shown by Fig. 3 accompanying. Its diameter is 21 inches and its penetration (P) into the smoke box is 12 inches. Results of nearly the same value were, however, obtained with stacks of smaller diameter having greater penetration. This may well be seen by reviewing the draft values obtained in return for a back pressure of 3.5 pounds, as given in Series 5, 6 and 7, Fig. 10. Thus, 21 inches diameter, 12 inches penetration gave a draft of 4.71; 19 inches diameter, 24 inches penetration gave a draft of 4.55, and 17 inches diameter, 26 inches penetration gave a draft of 4.32. From values thus presented it appears that as the degree of penetration increases the diameter of stack should be reduced. The effect is, in fact, of the same nature and degree as that which results from raising the exhaust tip. It is noteworthy also that these values for the plain inside stack are not materially better than those for the plain outside stack, a fact which was formulated as a conclusion resulting from the work of 1903.

6. INSIDE STACK, WITH FALSE TOP.— It had been planned to fit the front end with three different false tops located at 12 inches, 24 inches and 36 inches respectively from the top of smoke box, but the presence of the steam pipes made it difficult to fit the 12-inch top and as a consequence only the 24-inch and 36-inch drops were experimented upon. In each case stacks of different diameters were used, the outside height being always 29 inches. These arrangements and the draft resulting therefrom, when the back pres-

sure was 3.5 pounds, are shown by Series 8 and 9, Fig. 10. The best results were obtained with a stack 17 inches in diameter having a penetration of 24 inches, all as shown by Fig. 6. In all cases with the false top the 17-inch stacks gave best results. A comparison of these results with those quoted for plain outside stack and for plain inside stack show material improvement in draft values.

7. SUBSTITUTES FOR FALSE TOP.— The false top necessarily interferes with free access into the front end which fact makes it desirable that a way be found in which to secure the results derived from it by means which are more simple. It was suggested that experiments be made to determine the effect upon the plain inside stack of an annular ring or flange which might be considered as representing a portion of the false top. Responding to this suggestion rings of two diameters were used on 17-inch and 19-inch stacks having a penetration of 24 inches. It was found that the proportions shown by Fig. 7 gave substantially the same results as those obtained with the best arrangement of false top. (See Series 11, Fig. 11.) Believing that the results thus obtained pointed to the desirability of having a broader curve at the base of the stack and that when the proper proportions were understood the best results would be obtained from such a curved surface, the 17-inch stack was fitted with a bell to which, for purposes of experimentation, flanges of various widths were afterward added, with the result that those proportions which appear in Fig. 8 proved most satisfactory. These arrangements and the draft values obtained in connection therewith, are shown by Series 12, 13 and 14, Fig. 11. It will be noted that the best draft with the false top was 5.06; with the ring 5.05, and with the bell 4.98 — that is, these three arrangements are practically on an equality. No other arrangements were experimented upon which gave higher draft values than these.

8. SINGLE DRAFT PIPES.— Draft pipes of various diameters, adjusted to many different vertical positions, were tested in connection with plain stacks of the several diameters available. The elaboration of this phase of the work was very extensive. It was found that for the best results the presence of a draft pipe requires a smaller stack than would be used without it, but, that no possible combination of single draft pipe and stack could be found which gave a better draft than could be obtained by the use of a properly proportioned stack without the draft pipe. While the presence of a draft pipe will improve the draft when the stack is small, it will not do so when the stack is sufficiently large to serve without it. The best proportion and adjustment of single draft pipe and stack are shown by Fig. 4. The arrangement of draft pipes covered by the experiments and the draft resulting therefrom are shown by Series 16 to 69, Figs. 12 to 17 inclusive.

9. DOUBLE DRAFT PIPES.— Double draft pipes of various diameters and lengths, and having many different positions within the front ends, all in combination with stacks of different diameters, were included in the

experiments with results which justify a conclusion similar to that reached with reference to single draft pipes. Double draft pipes make a small stack workable. They can not serve to give a draft equal to that which may be obtained without them, provided the plain stack is suitably proportioned. The arrangements and proportions giving the best results are those shown by Fig. 5, and the different arrangements employed with the draft values resulting by Series 70 to 87, Figs. 18 and 19 inclusive.

10. THE LENGTH OF FRONT END.— The experiments involving different lengths of front end only, appear to be inconclusive. The range of these experiments included the length of the front end normal to the locomotive which is 65.75 inches, with successive reductions therefrom of 4½ inches, 8 7-16 inches and 20 inches respectively, obtained in each case by fitting in a false front. The fitting was well done, the work being made practically tight, notwithstanding which fact it was found that the longest and shortest ends experimented with gave practically identical results, while the lengths between these limits gave results which were somewhat inferior. The peculiar character of the results as first obtained led to a complete duplication of the work after a considerable interval had elapsed, with results which were identical with those first obtained. So far as the experimental results give a solution to this problem, they point to a length of 66 inches or 46 inches as equally satisfactory, and suggest that intermediate lengths are to be avoided. The arrangements employed and the draft values resulting appear as Series 15, Fig. 11.

11. A SUGGESTION AS TO A STANDARD FRONT END is presented as Fig. 9, which, with the following equations referring thereto, may be accepted as a summary of the conclusions to be drawn from all experiments made.

For best results, make H and h as great as practicable.

Also make

$d = .21D + .16h.$

$b = 2d$ or $.5D.$

$P = .32D.$

$p = .22D.$

$L =$ (not well established).

$= .6D$ or $.9D$, but not of intermediate values.

While the drawing is a simple one, to be put forth as a result of so elaborate a series of experiments, it goes without saying that the latter have been valuable quite as much for the things they prove useless as for the proportions of details which they serve to define. For example, it will be seen that the suggested standard does not include draft pipes, and that it includes a stack of comparatively large diameter having a bell at the lower end of dimensions quite beyond those now common in American practice.

12. A SUMMARY OF ALL RESULTS.— To make comparisons easily possible, the draft obtained when the back pressure equals 3.5 pounds has

been taken from curves presented elsewhere, and combined with a drawing showing the arrangements to which they apply. These summarized statements are presented herewith as Figs. 10 to 19, inclusive. By their aid one may familiarize himself with the extent and significance of the experiments. For purposes of the laboratory, each different arrangement was given a series number, and in the summary reference to this number appears within a circle at the upper left-hand corner. The following is a brief key to the diagrams:

Series 1 — 29-inch stacks of different diameters, draft pipes and diaphragm normal to the engine.
Series 2 — Same with draft pipes removed.
Series 3 — Same with draft pipes and extension diaphragm removed.
Series 4 — 47-inch stack of different diameters.
Series 5-7 — Plain inside stacks.
Series 6-9 — False tops.
Series 10 — False top with diaphragm normal to engine.
Series 11 — Annular rings upon base of stacks.
Series 12-14 — Stacks having bell-shaped base.
Series 15 — Variable lengths of front end.
Series 16-21 — 13-inch single draft pipe in combination with 15-inch stacks.
Series 22-27 — 13-inch single draft pipe in combination with 19-inch stacks.
Series 28-33 — 13-inch single draft pipe in combination with 23-inch stacks.
Series 34-39 — 15-inch single draft pipe in combination with 15-inch stacks.
Series 40-45 — 15-inch single draft pipe in combination with 19-inch stacks.
Series 46-51 — 15-inch single draft pipe in combination with 23-inch stacks.
Series 52-57 — 17-inch single draft pipe in combination with 15-inch stacks.
Series 58-63 — 17-inch single draft pipe in combination with 19-inch stacks.
Series 64-69 — 17-inch single draft pipe in combination with 23-inch stacks.
Series 70-72 — 13-inch and 15-inch draft pipes in combination with 15-inch stacks.
Series 73-75 — 13-inch and 17-inch draft pipes in combination with 15-inch stacks.
Series 76-78 — 13-inch and 15-inch draft pipes in combination with 19-inch stacks.
Series 79-81 — 13-inch and 17-inch draft pipes in combination with 19-inch stacks.

Series 82-84 — 13-inch and 15-inch draft pipes in combination with 23-inch stacks.

Series 85-87 — 13-inch and 17-inch draft pipes in combination with 23-inch stacks.

A more elaborate presentation of methods and results is given in the accompanying Appendix.

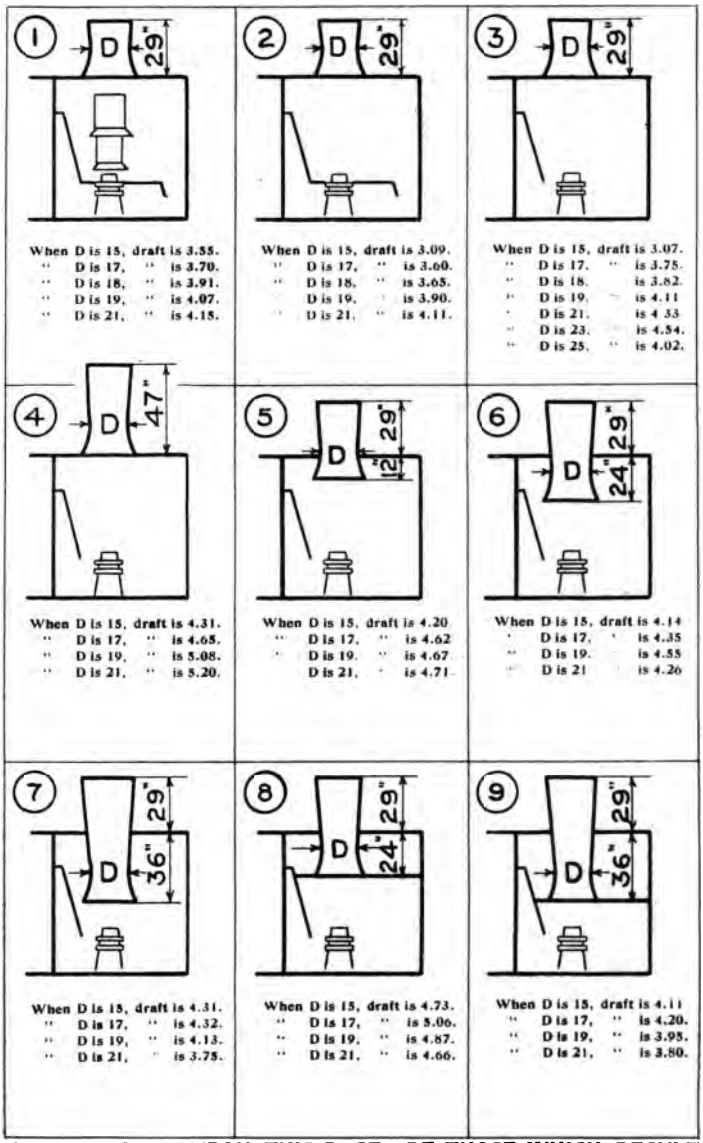
13. Disposition of Equipment. — The experimental equipment of stacks and draft pipes employed in the tests has been left in the keeping of the University. It is the understanding of your committee that they will, for a time at least, be preserved in the locomotive museum, though it is possible that the demand for room may eventually require them to be scrapped. So far as your committee is concerned, they are disposed of.

14. An Extension of Courtesy to the New York Central Lines.—At the conclusion of its formal work and with the co-operation of the University authorities, your committee undertook and completed a minor investigation under the direction of the New York Central Lines, the results of which have been reported directly to Mr. J. F. Deems, General Superintendent of Motive Power. The opportunity thus embraced whereby courtesy was shown the Railroad Company, permitted your committee to make some slight return for the assistance rendered the Association by the New York Central Railroad Company.

Respectfully submitted,

H. H. Vaughan, Chairman,
F. H. Clark,
Robert Quayle,
A. W. Gibbs,
W. F. M. Goss,
G. M. Basford,

Committee.


1
D
29"
When D is 15, draft is 3.55.
" D is 17, " is 3.70.
" D is 18, " is 3.91.
" D is 19, " is 4.07.
" D is 21, " is 4.15.
2
D
29"
When D is 15, draft is 3.09.
" D is 17, " is 3.60.
" D is 18, " is 3.65.
D is 19, is 3.90.
D is 21, " is 4.11.
3
D
29"
When D is 15, draft is 3.07.
" D is 17, " is 3.75.
" D is 18, is 3.82.
" D is 19, is 4.11
D is 21, is 4.33
" D is 23, is 4.54.
" D is 25, " is 4.02.
4
D
47"
When D is 15, draft is 4.31.
" D is 17, " is 4.65.
" D is 19, " is 5.08.
" D is 21, " is 5.20.
5
D
12"
29"
When D is 15, draft is 4.20.
" D is 17, " is 4.62
D is 19, " is 4.67
D is 21, is 4.71
6
D
24"
29"
When D is 15, draft is 4.14
D is 17, is 4.35
" D is 19, is 4.55
" D is 21 is 4.26
7
D
36"
29"
When D is 15, draft is 4.31.
" D is 17, " is 4.32.
" D is 19, " is 4.13.
" D is 21, is 3.75.
8
D
24"
29"
When D is 15, draft is 4.73.
" D is 17, " is 5.06.
" D is 19, " is 4.87.
" D is 21, " is 4.66.
9
D
36"
29"
When D is 15, draft is 4.11
" D is 17, " is 4.20.
" D is 19, " is 3.95.
" D is 21, " is 3.80.

DRAFT VALUES UPON THIS PAGE ARE THOSE WHICH RESULT FROM AN EXHAUST PRESSURE OF 3.5 POUNDS.

FIG. 10.

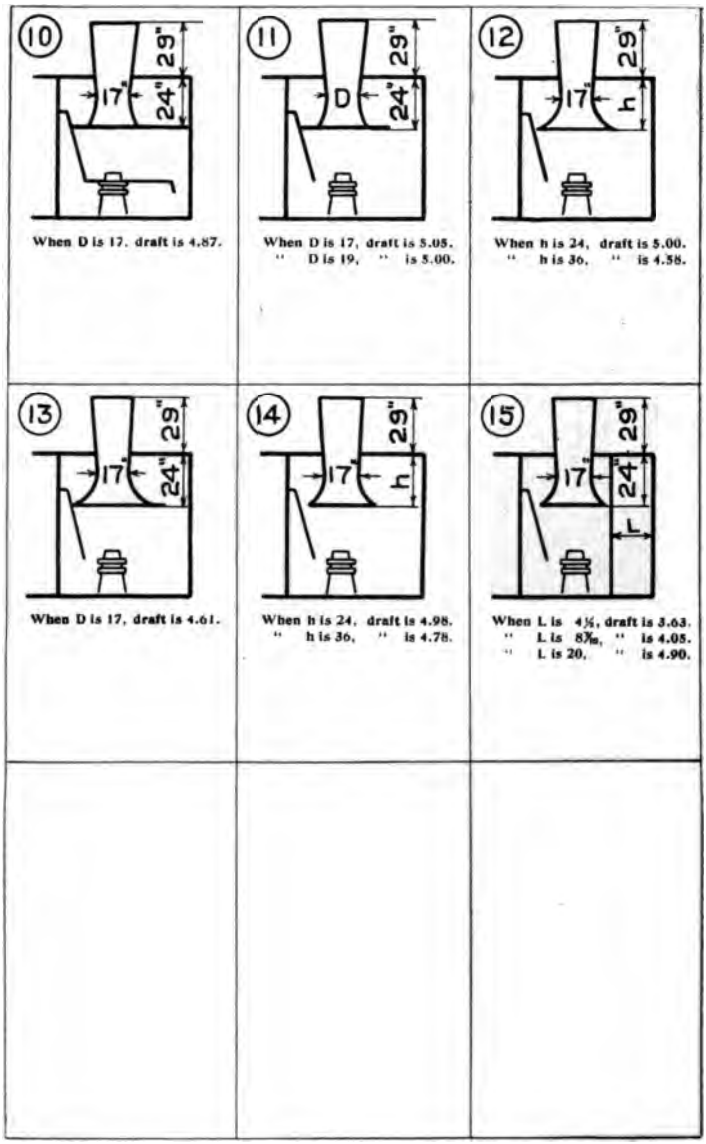


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FIG. 11.

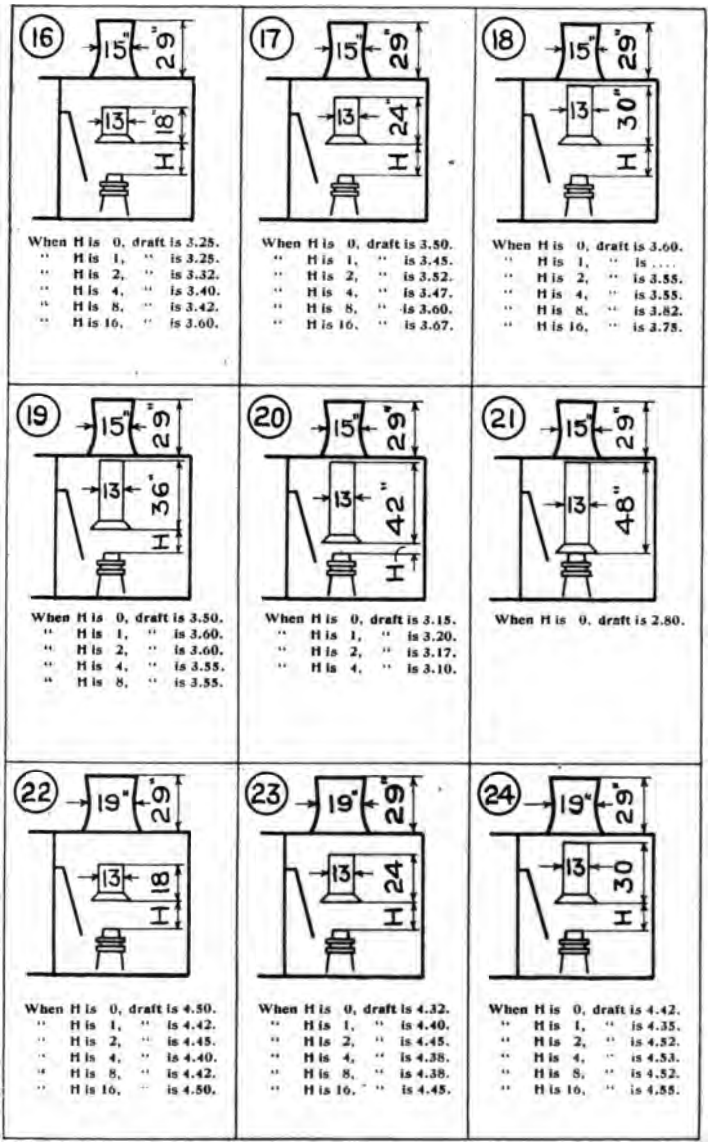

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FIG. 12.

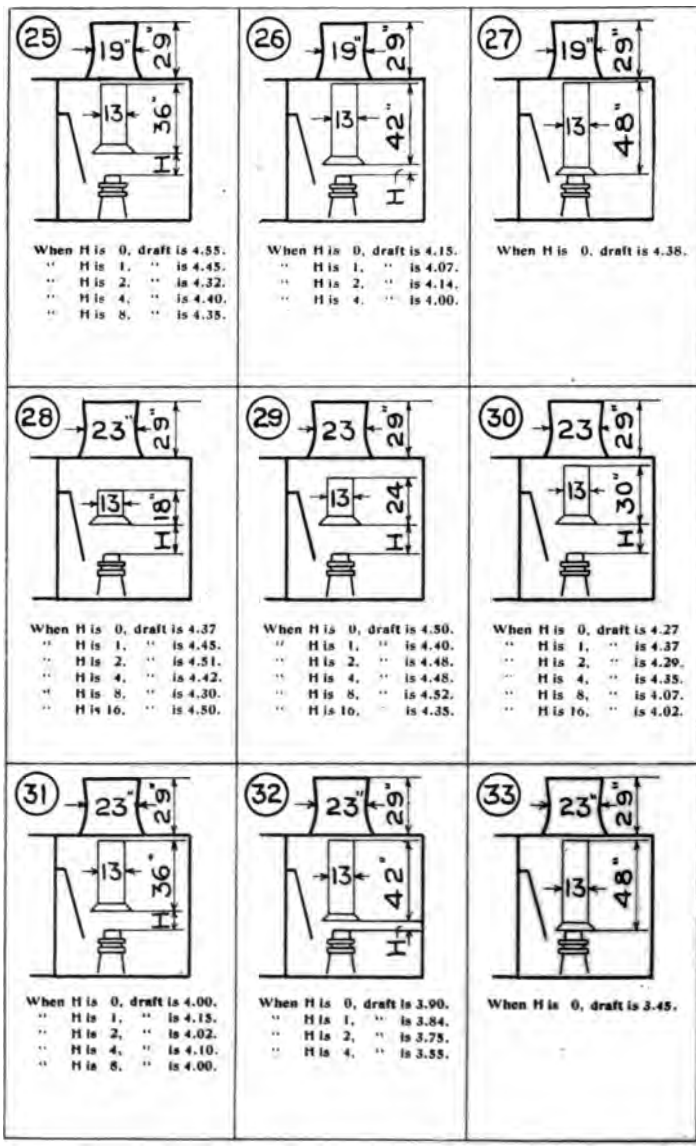

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FIG. 13.

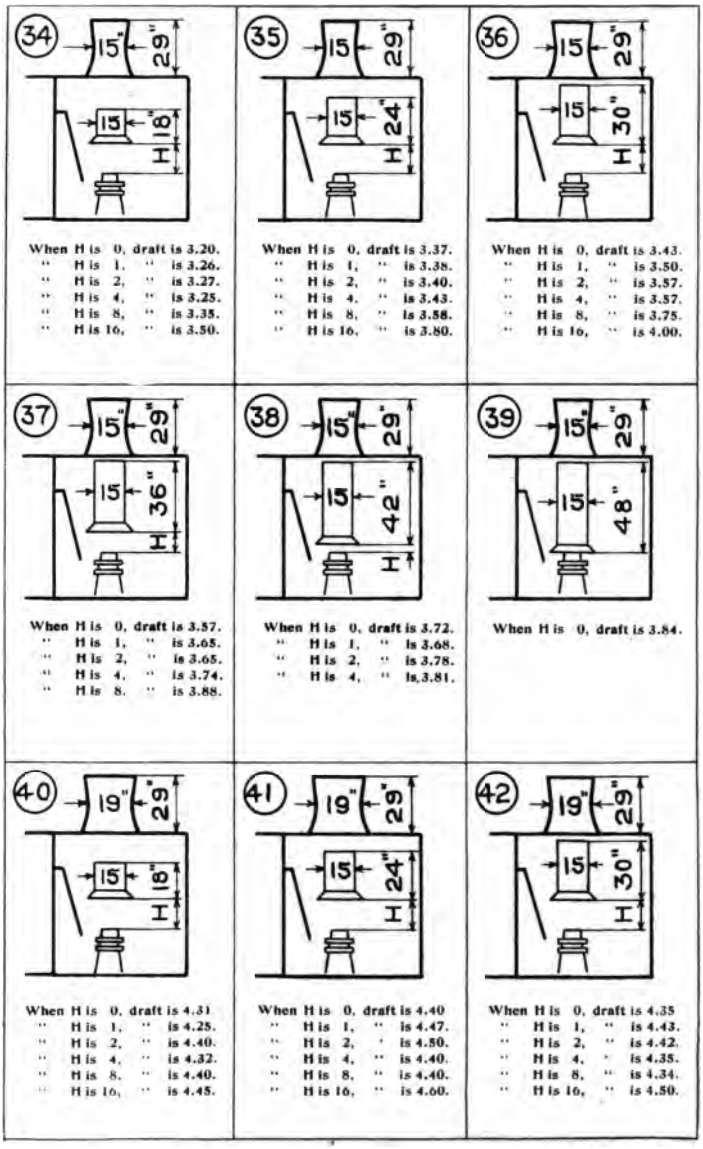

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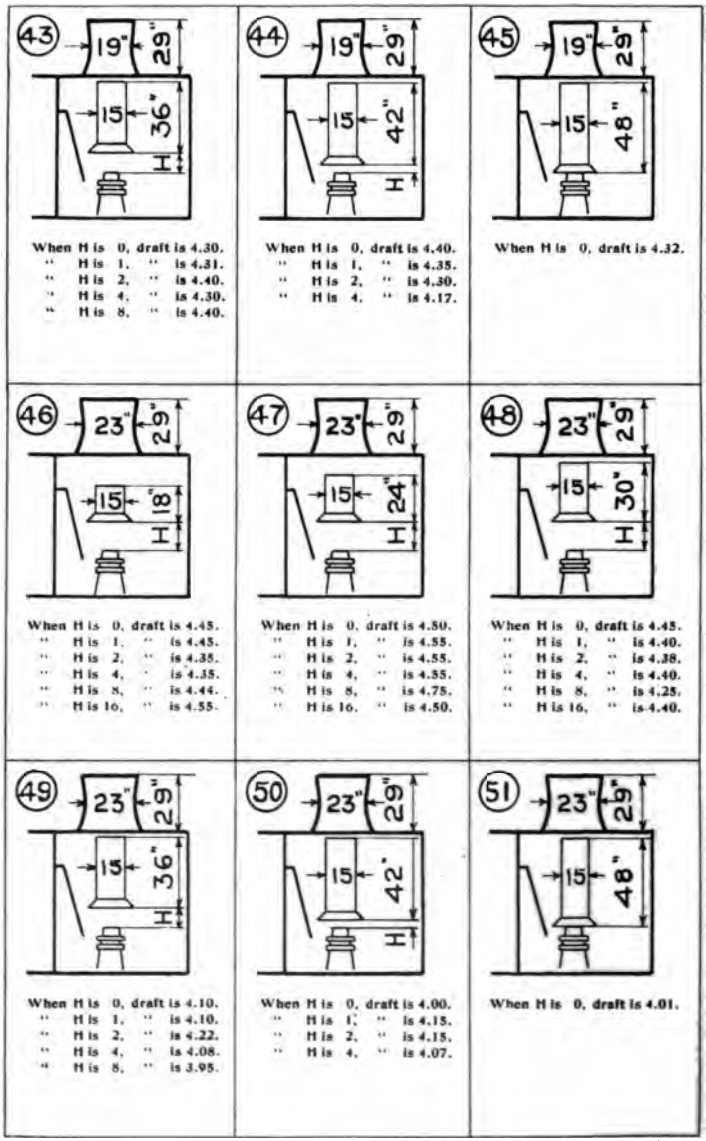
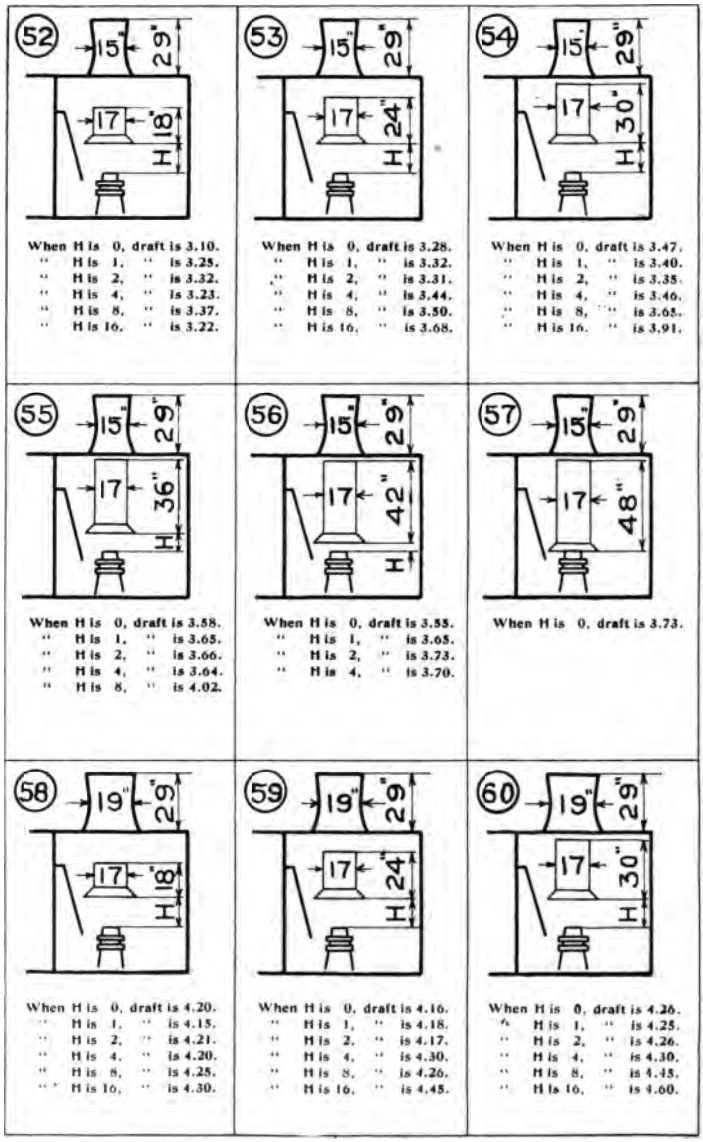
FIG. 14.



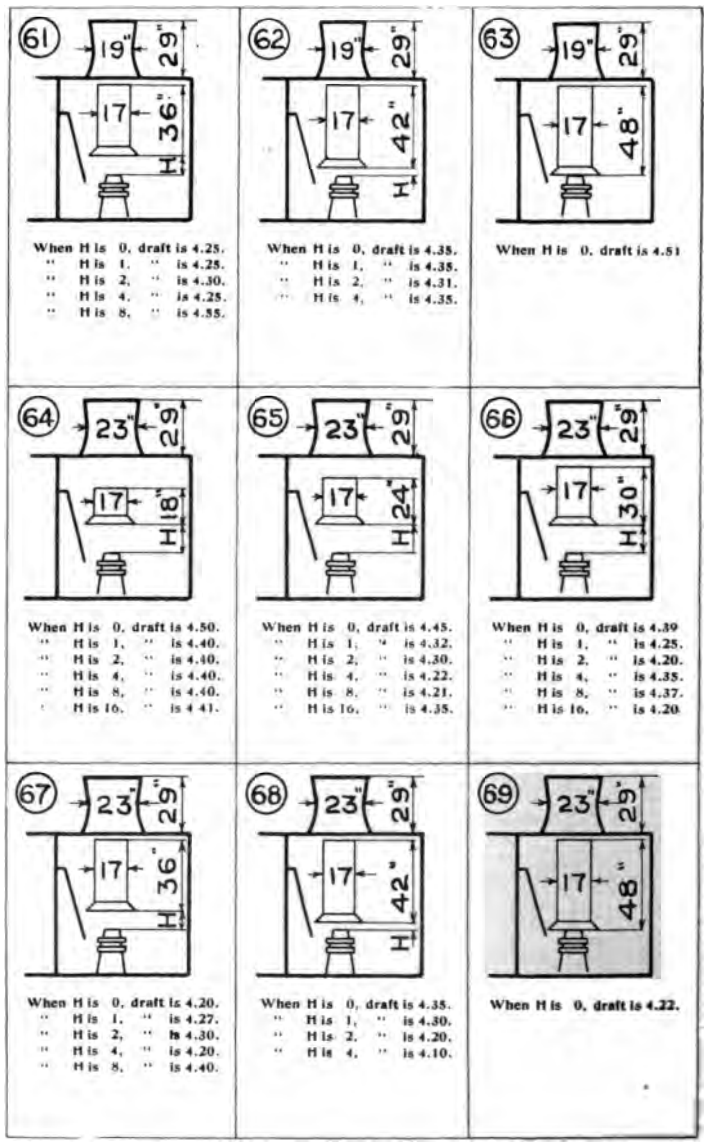
DRAFT VALUES UPON THIS PAGE ARE THOSE WHICH RESULT FROM AN EXHAUST PRESSURE OF 3.5 POUNDS.

FIG. 15.



DRAFT VALUES UPON THIS PAGE ARE THOSE WHICH RESULT FROM AN EXHAUST PRESSURE OF 3.5 POUNDS.

FIG. 16.



DRAFT VALUES UPON THIS PAGE ARE THOSE WHICH RESULT FROM AN EXHAUST PRESSURE OF 3.5 POUNDS.

FIG. 17.

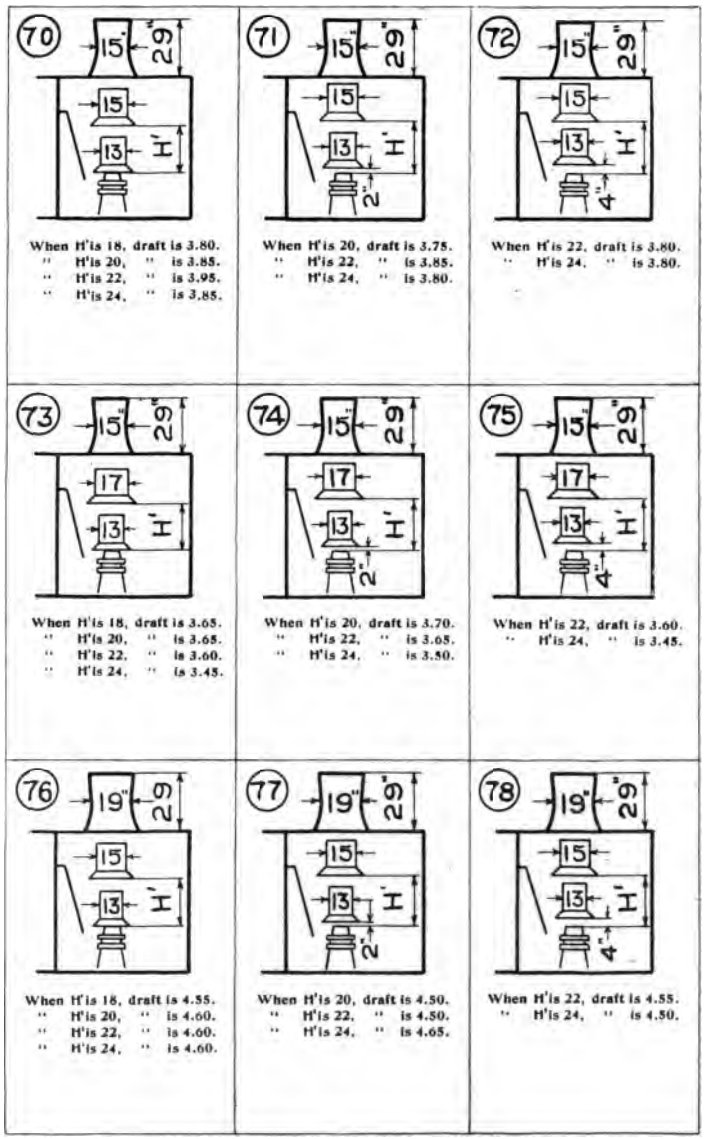


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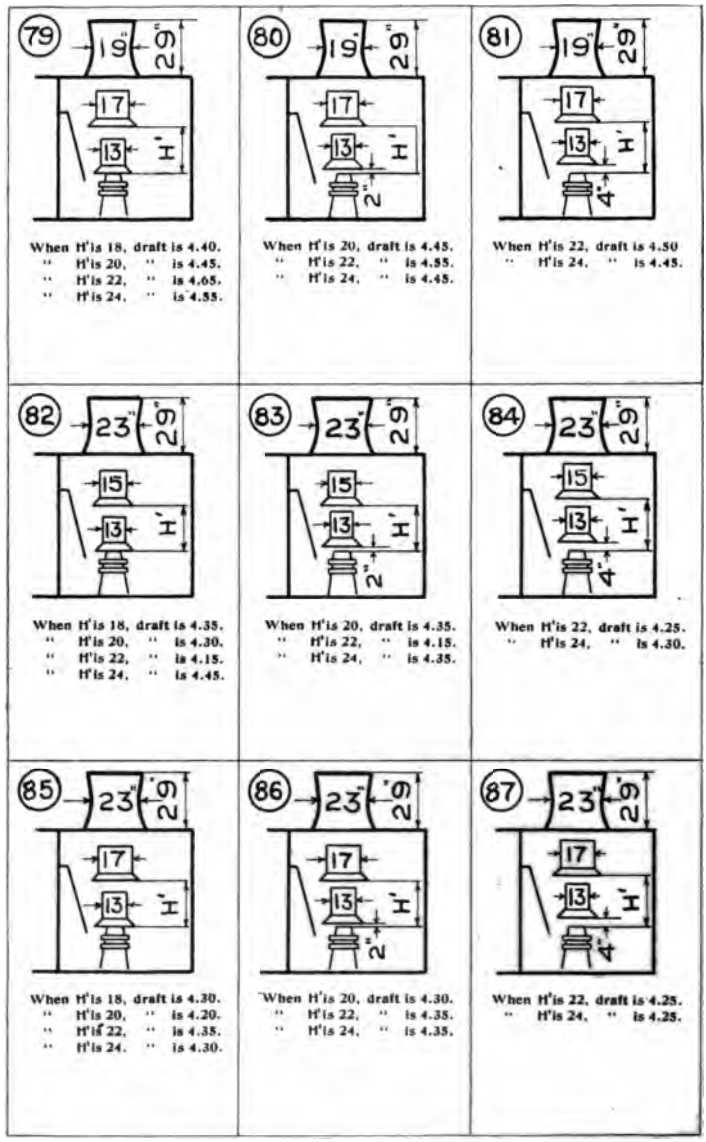
FIG. 18.



DRAFT VALUES UPON THIS PAGE ARE THOSE WHICH RESULT FROM AN EXHAUST PRESSURE OF 3.5 POUNDS.

FIG. 19.

THE TESTS.

LETTER OF TRANSMITTAL.

To the Committee on Locomotive Front Ends:

GENTLEMEN — 15. In obedience to arrangements previously made, the Engineering Laboratory of Purdue University has, by your direction, undertaken an elaborate series of experiments designed to disclose the best proportions for certain details entering into the construction of locomotive front ends. Purdue's locomotive laboratory has been vacated for the reception of a larger engine supplied by your committee, and the work in connection therewith has been vigorously pushed during a considerable portion of the present school year. The general supervision of the work has been in charge of W. O. Teague, Assistant Professor of Experimental Engineering; the processes of the laboratory have proceeded under the immediate direction of L. E. Endsley, Instructor in charge of the locomotive laboratory; and editorial assistance has been rendered by Fritz Ernst, Instructor in Railway Mechanical Engineering. Important aid has also been rendered by Senior students in the department of Mechanical Engineering. Much time has been given by Messrs. M. M. Sheedy, J. E. Poindexter, H. E. Smith, H. C. Jarvis, W. P. O'Connor, T. B. Keim and L. E. Rush, each of whom selected a portion of your committee's investigation as a subject for his graduating thesis. All other members of the class have taken their turns as observers in the laboratory for at least three different afternoons. The University staff thus organized for the work has been aided by an effective corps of observers, computers and laboratory attendants sustained at the expense of the Association.

I can not refrain from calling the attention of the committee to the degree of care which has been bestowed upon the experimental processes. There has been no shiftless work, nothing has been half done. In the attachment of experimental apparatus everything has been truly placed, closely fitted, and securely fastened. The predetermined conditions under which the tests were to be run have been carefully observed. The log of numerical results has been supplemented by a graphical record which has been extended as the work has proceeded. A point out of line with others has at once suggested a repetition of the test it represented, so that the close of each day saw a distinct portion of the whole work definitely completed. An illustration of the care bestowed is to be found in the accuracy with which the back pressure upon the engine was observed. In previous experiments involving the front end, this factor has proven a difficult one to determine, owing to the tendency of water to accumulate in the gauge or its pipe connections. In the present work, arrangements which were ingenious, yet simple, permitted the gauge to fill with water but allowed its presence to be taken into account in the final reading.

Altogether, approximately one thousand different tests were run and the earlier ones were run in duplicate. The mileage of the New York Central locomotive No. 3929 while on the plant was 2,390.

The detailed report of Professor Teague which follows, deals with much that has been attempted and all that has been accomplished.

Respectfully submitted,

W. F. M. Goss.

ENGINEERING LABORATORY, PURDUE UNIVERSITY, May, 1906.

PROFESSOR TEAGUE'S REPORT.

16. THE LOCOMOTIVE.— The New York Central & Hudson River Railroad Company's locomotive No. 3929 (Fig. 20) used in the tests, is of the Atlantic type. It was built by the Schenectady Works of the American Locomotive Company. Its principal dimensions are as follows:

Weight in working order (pounds)	176,000
Normal weight on drivers (pounds)	95,000
Weight on truck (pounds)	42,000
Weight on trailing wheels (pounds)	38,400
Diameter of cylinder (inches)	21
Stroke of pistons (inches)	26
Type of valve	Piston
Diameter of valves (inches)	12
Boiler pressure (pounds)	200
Diameter of boiler first ring (inches)	72
Number of tubes	396
Outside diameter of tubes (inches)	2
Length of tubes (feet)	16
Length of firebox (inches)	96⅛
Width of firebox (inches)	75⅜
Depth of firebox:	
Forward end (inches)	80¼
Back " "	69
Area of heating surface in tubes (sq. ft.)	3298.08
Area of heating surface in firebox (sq. ft.)	180
Area of surface in arch firebox tubes (sq. ft.)	27.09
Total heating surface (sq. ft.)	3505.17
Area of grate (sq. ft.)	50.32
Diameter of smokebox (inches)	74
Length of smokebox (inches)	65¾
Height of stack above smokebox (inches)	29
Diameter of stack at choke (inches)	18
Diameter of exhaust tip (inches)	5 11-16
Height of exhaust tip above bottom of front end (inches)	25

17. EQUIPMENT FOR BURNING OIL.— Oil was used as fuel to secure constant conditions at the grate. The equipment for handling the oil was the same as that employed in previous stack tests conducted at Purdue University and is described in detail in the report of these tests which appears in the *American Engineer,* April, 1902.

In the preparation of the firebox for oil, a curved floor was substituted for the usual grate. This was supported by six 1 x 5 inch wrought-iron bars extending across the firebox and bolted to the mud-ring. Over this was fitted a covering of ⅛-inch plate strengthened where necessary by angle irons. Upon this metal floor two courses of fire brick were laid in grout. Side walls also were constructed between this floor and the line of the arch tubes, all as shown by Fig. 21. The floor of the firebox thus described was pierced by three ports for the admission of air, the dimensions of which are well shown upon the drawings. As it was essential that the degree of freedom with which air was allowed to enter the firebox should remain constant throughout the tests, great pains were taken to make all parts of this special construction secure. Angle irons were used under the side walls and around all openings and the brickwork was put in with such care that it remained throughout the tests in excellent condition. To protect the frames and axles from reflected heat through the ports, a supplemental shield of brickwork on a metal foundation occupied a place similar to that of the usual ash pan. This also is shown in Fig. 21. Fuel oil was delivered by a single burner inserted under the mud-ring in a manner made possible by the curved form of the floor of the firebox.

18. PRESSURE AND DRAFT GAUGES.— Pressures were observed by means of gauges connected to the smokebox in front and back of the diaphragm, with the firebox by means of a hollow stay bolt, and to the exhaust steam passage of the saddle. The points of connection are shown at C, B, A and D in Fig. 20.

For observing the pressure in the smokebox, ordinary U-tube gauges (Fig. 22) were used, with shot in the lower bend of the tube to steady the liquid. Each gauge was fitted with a sliding scale by use of which the zero of the scale could easily be adjusted to agree with the height of one of the columns.

Two special gauges, designed by Mr. Endsley, were employed in securing readings of the back-pressure in the exhaust cavity, a mercury gauge which was used when the back-pressure was high, and a water gauge for use when the pressure was lower. The former consisted of an ordinary U-tube (Fig. 23) having an arrangement for correcting the reading to neutralize the effect of water condensation which tended to collect on the pressure side of the gauge. The lower portions of the U-tube contained mercury. A ½-inch pipe led from the exhaust cavity to the gauge from which point a 1-inch pipe led through a valve to the atmosphere, the gauge connecting with the larger pipe. The valve was normally open to keep the ½-inch pipe free from water, notwithstanding which fact, water

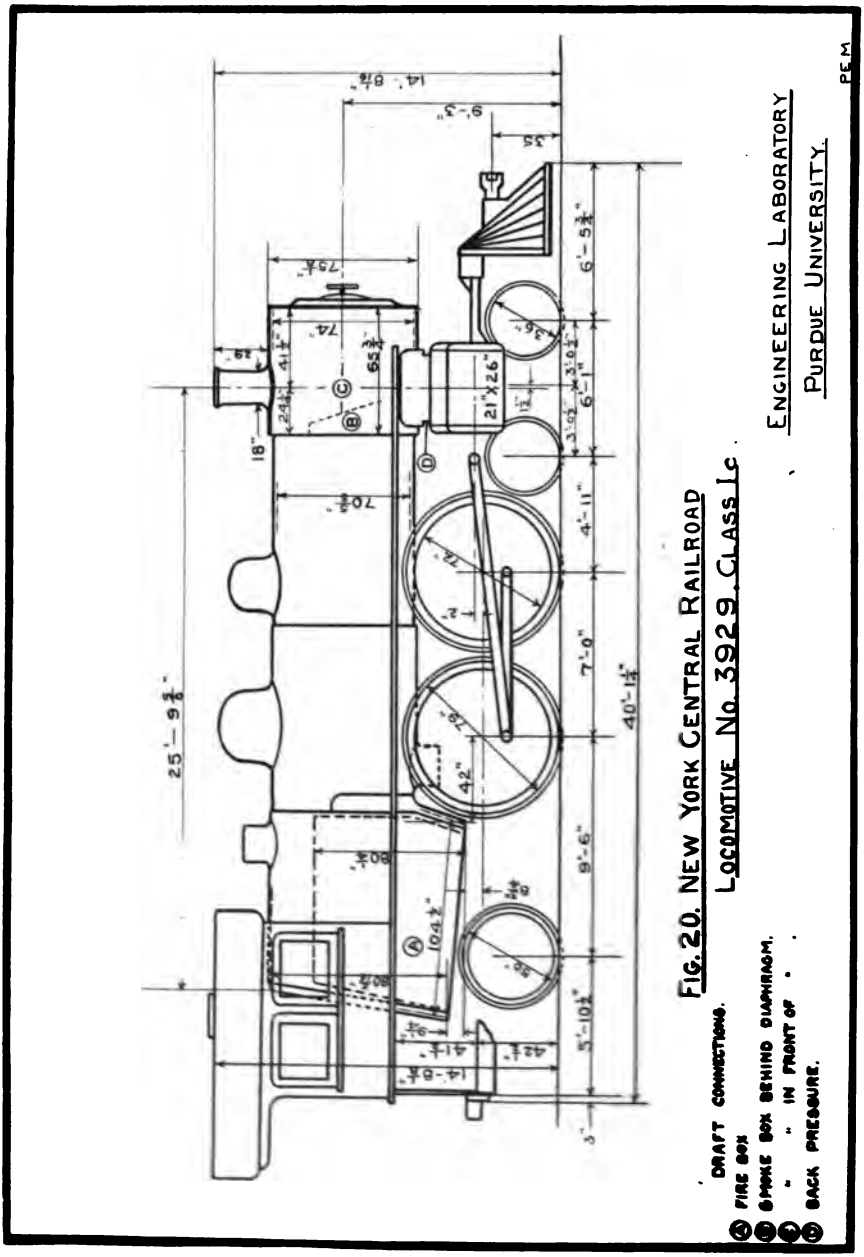


FIG. 20. NEW YORK CENTRAL RAILROAD LOCOMOTIVE No. 3929, CLASS Le

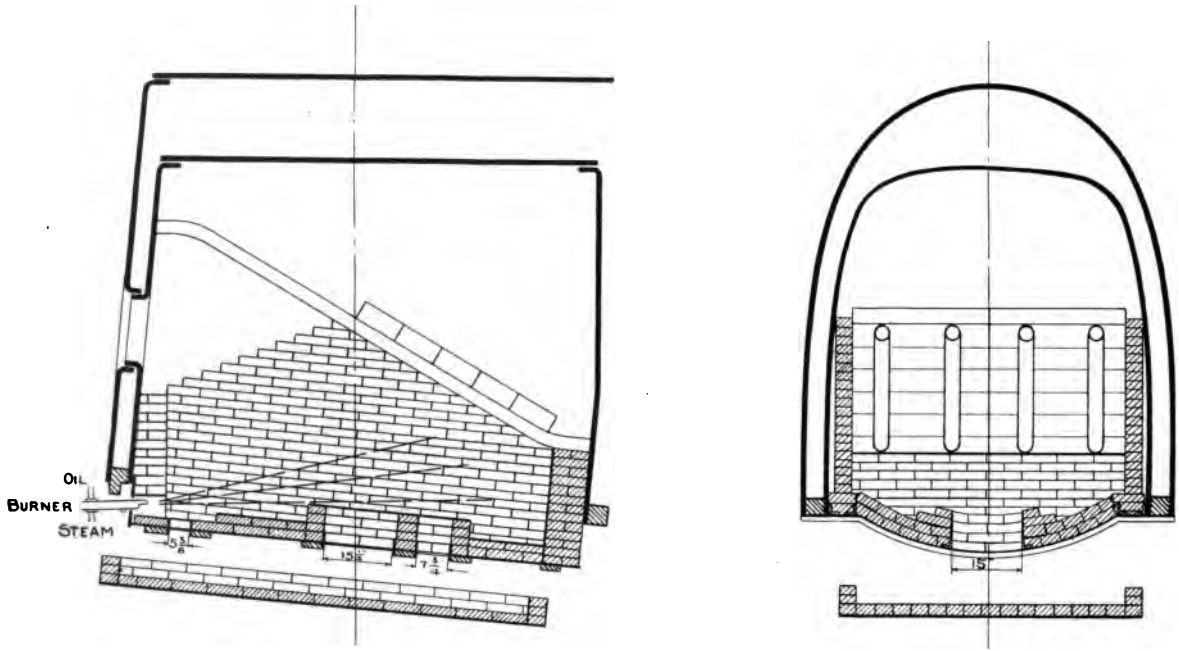


FIG. 21. GENERAL ARRANGEMENT OF FIRE BOX FOR BURNING OIL.

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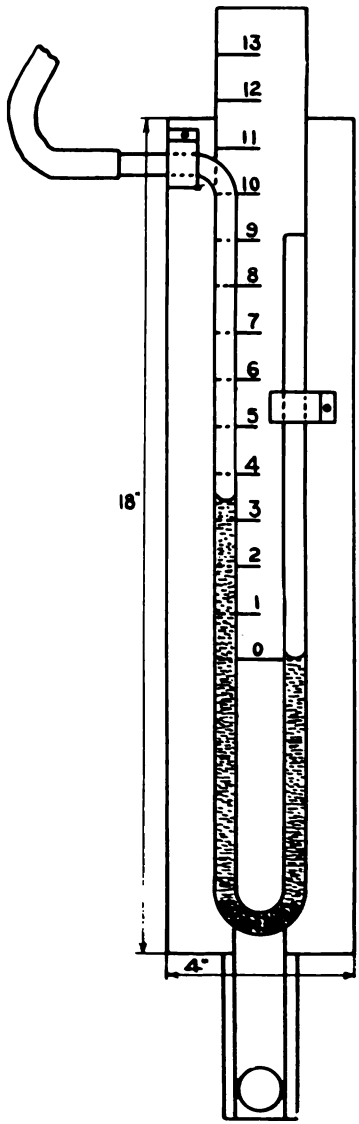

FIG. 22. DRAFT GAGE.

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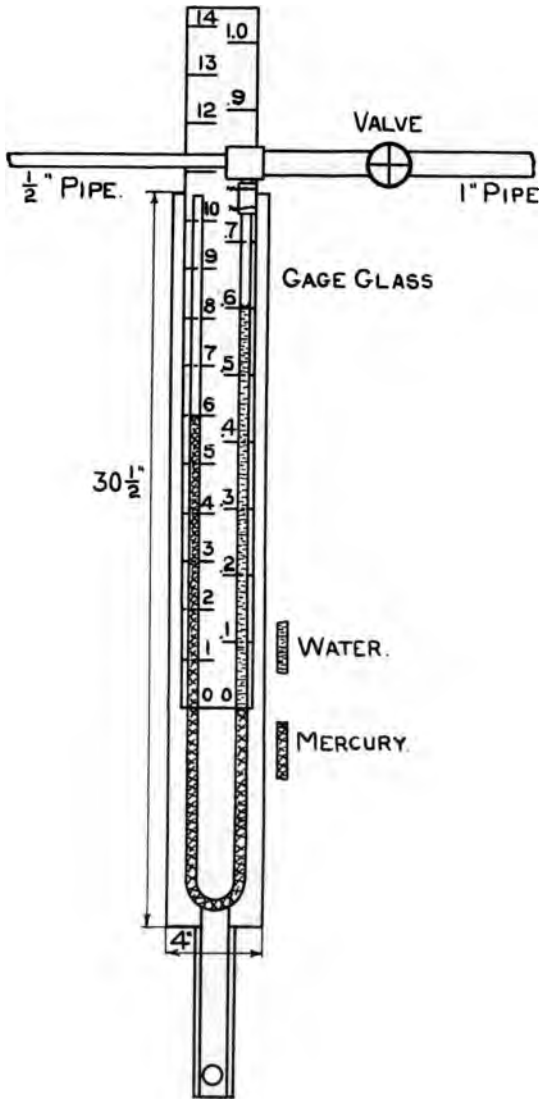

FIG. 23. BACK PRESSURE GAGE.

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of condensation would fill the leg of the U-tube which is connected with the pipe above the mercury. A sliding scale on the gauge provided graduations on the pressure side, reading the pressure in pounds per square inch of the column of water in the tube. Graduations on the open side read pressure in pounds per square inch, of the column of mercury. Both graduations started from the same zero point. In reading the scale the zero point was made to coincide with the top of the mercury column on the pressure side. The readings on the open side were larger than normal by an amount equal to the weight of the column of water on the opposite side. The correct reading was assumed to be that of the mercury column on the open side minus that of the water column on the pressure side. Referring to Fig. 23, the reading on the open side is 6 pounds, on the pressure side it is .6 of a pound. The corrected reading is 5.4 pounds. In reading the gauge the 1-inch valve was closed and the reading taken as described above.

For tests at slow speeds the back-pressure mercury gauge was not sufficiently delicate, and one using water alone was employed. (Fig. 24.) For no pressure the water in the two sides of the tube was at the same level reading zero. Pressure on the closed side caused water to overflow on the open side and the pressure could be read directly on the scale downward. For slightly greater pressures a short additional tube was attached to the open end with a scale reading from zero upward. The pressure then was the sum of the reading from zero down to the column of water in the closed side, plus the reading from zero up on the open side. A small diaphragm with a 1-64-inch opening was used in the lower bend of the tube to reduce the fluctuations due to rapid changes of pressure.

For observing the pressure in the firebox a Sargent gauge (Fig. 25) made by the Schaeffer & Budenberg Manufacturing Company was employed. This gauge consists of a nickel-plated brass cylinder closed at both ends, around which a flexible transparent celluloid tube is wound, the bottom end of which is in communication with the interior of the brass chamber. The cylinder is filled with water to zero mark through a cock at the top, the same level showing in the tube. The water level is read from a scale on the cylinder and so arranged that one inch motion vertically is represented by 9-inch movement in the tube. The instrument readily permits vertical changes to be read directly to 1-100 of an inch. For convenience in taking the readings the gauge is pivoted by means of an extension of the lower head of the cylinder to form a bearing in the supporting bracket which allows the gauge to be revolved at will on its vertical axis. The connection with a hollow stay bolt giving access to the firebox is made through the cock on the top, any reduction of pressure at this point causing the liquid in the tube to fall, the reading being down from zero.

19. THE STACKS.— The tests included outside and inside stacks, the latter with and without false tops.

The outside stacks (Figs. 28 and 29) were of two heights, 29 inches and 47 inches, the lesser height being that normal to the engine. Stacks of 29 inches in height were employed having diameters of 15 inches, 17 inches, 19 inches, 21 inches, 23 inches and 25 inches, respectively, and of 47 inches in height, of 15 inches, 17 inches, 19 inches and 21 inches, respectively. The experiments involving the use of this apparatus are designated elsewhere as Series 1 to 4 and 16 to 87, inclusive.

The inside stacks (Figs. 30 and 31) in their greatest length were 65 inches long, including a normal length of 41 inches, together with two detachable sections, 12 inches in length each. These proportions gave the longest stack an inside penetration of 36 inches with the normal outside height of 29 inches. The 24-inch and 12-inch inside penetrations were obtained by removing one or both of the detachable sections, keeping the outside height 29 inches. The experiments involving the use of this apparatus are designated elsewhere as Series 5 to 15, inclusive.

A designating symbol of three terms has been used in indicating the different stacks experimented upon. This is in the form of

$$D + H - h$$

in which D is the diameter of the stack at the choke, H, its height above the boiler and h the extension inside the boiler. Thus stack $15 + 29 - 0$ in an outside stack 15 inches in diameter and 29 inches high. Stack $15 + 29 - 24$ is an inside stack 15 inches in diameter, 29 inches above and 24 inches below the top of the boiler. These symbols are employed in connection with all data presented.

The inside stacks being smaller in diameter than the opening in the top of the smoke box, a space was left between the stack and the boiler shell which was closed by the use of fire clay. The clay was packed around the stack and was supported on a circular plate bolted to the inside of the front end. The plates were of sizes to fit the different diameters of stacks and were made in two sections embracing 180° each. A special casting (Fig. 32) angular in section, was bolted around the stack opening on the outside of the front end. Bolts passing through the vertical lugs of this casting and through the stack held the latter in position.

20. False Tops.—False tops were used in connection with inside stacks having 24-inch inside penetration (Fig. 33) and with stacks having 36-inch inside penetration (Fig. 34). They were built up of plate and angle irons so arranged as to provide in each case, an opening 34 inches square under the center of the stack. The base of the inside stacks of different diameters was riveted to a square plate of the proper dimensions to fill this opening in the false tops. The false tops were securely bolted to the sides of the smoke box and curved pieces were added to improve the shape of the space below them. In fitting the false top, all work was made tight. The experiments involving the use of this apparatus are designated elsewhere as Series 8 to 10, inclusive.

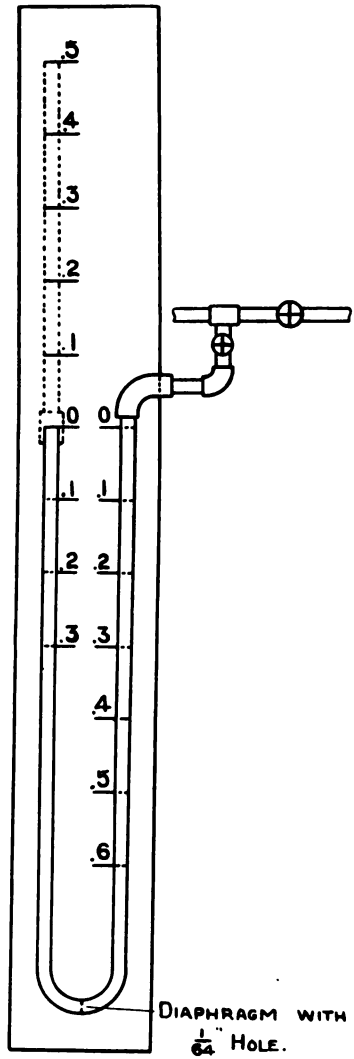

FIG. 24. WATER BACK PRESSURE GAGE.

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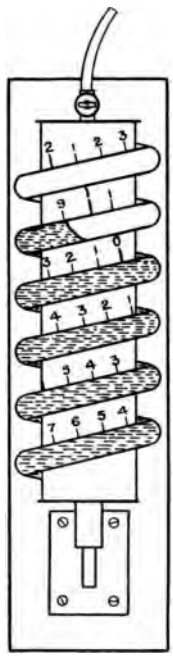

FIG. 25. SARGENT GAGE.

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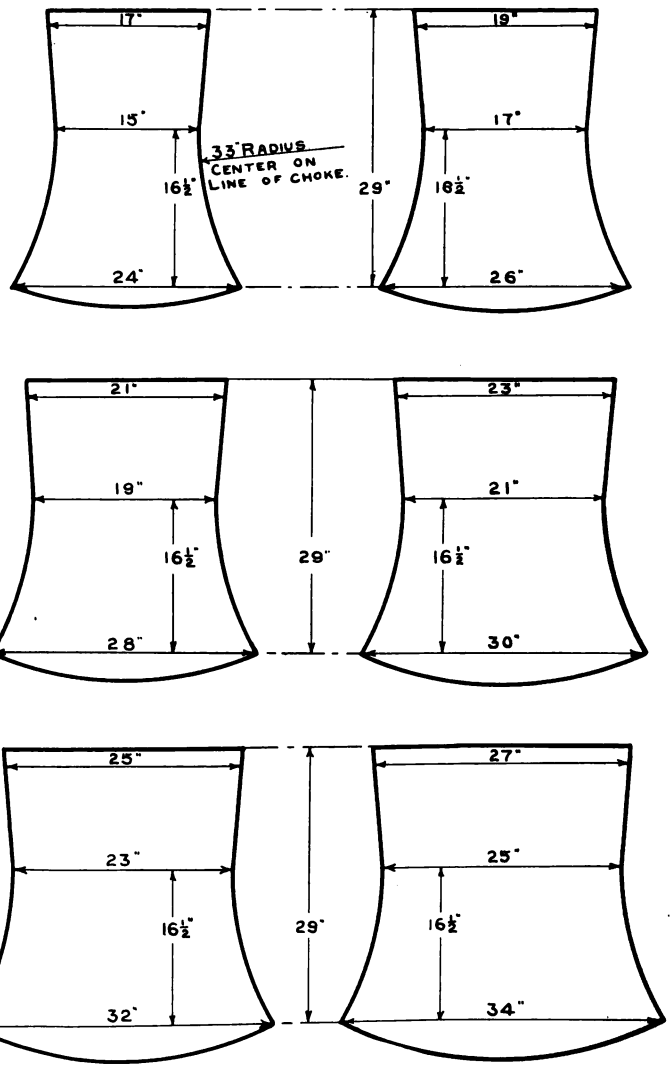

FIG. 26. OUTSIDE STACKS.

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FIG. 27. OUTSIDE STACKS.

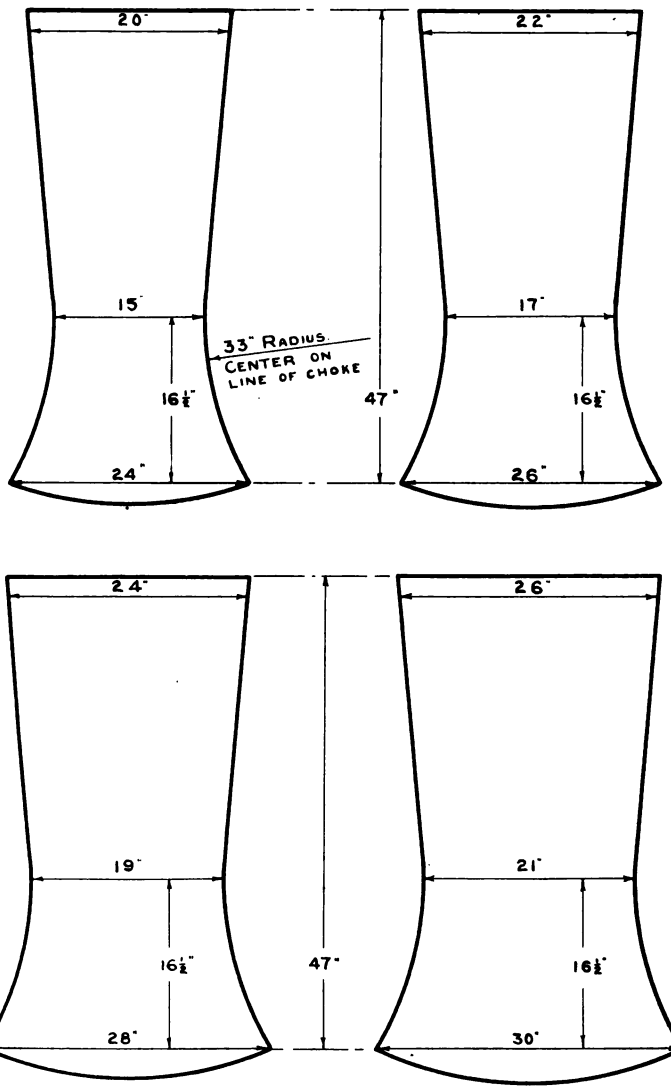

FIG. 28. OUTSIDE STACKS.

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FIG. 29. OUTSIDE STACKS.

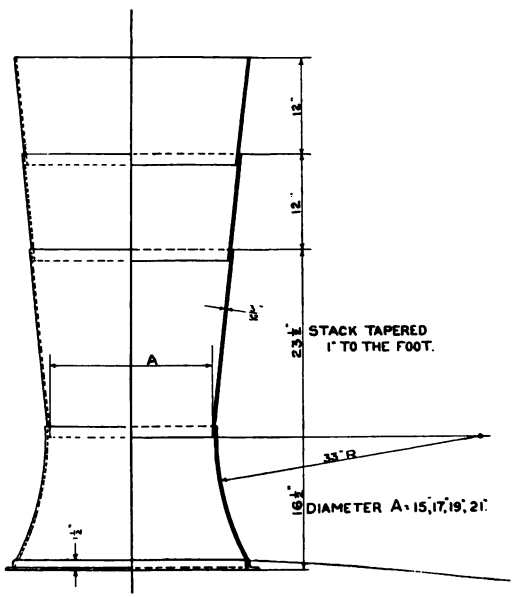

FIG. 30. INSIDE STACKS.

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FIG. 31. INSIDE STACKS.

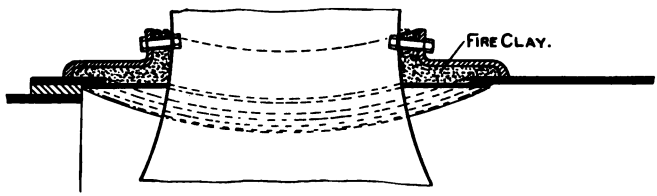

FIG. 32. INSIDE STACK SUPPORT.

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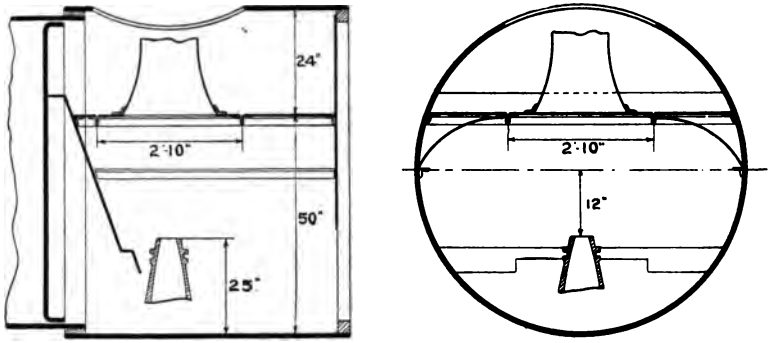

FIG. 33. 24 INCH FALSE TOP.

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PURDUE UNIVERSITY.

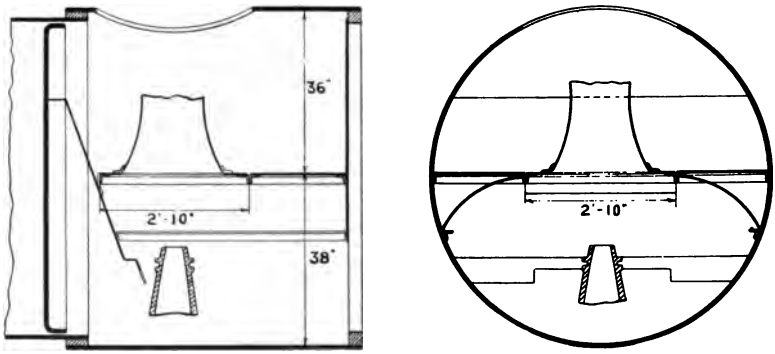

FIG. 34. 36 INCH FALSE TOP.

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21. SPECIAL STACKS.—Special stacks consisting of certain of those already described, fitted with circular plates fastened to the base, or with the base proper completely changed were as follows:

Circular plates 10 inches wide (Fig. 35) were fastened to the bottom of the 17 + 29 — 24 and 19 + 29 — 24 inch stacks.

The base of the 17 + 29 — 24 inch stack was removed at the choke and replaced by two other bases, one flanged to a diameter of 34½ inches at the bottom (Fig. 36) and the other to a diameter of 44½ inches (Fig. 37). The stack above described with the 44½-inch base was further modified by the addition of a circular plate five inches wide to the base giving a diameter at the base of 54½ inches (Fig. 38). The experiments involving the use of this apparatus are designated elsewhere as Series 11 to 15, inclusive.

22. FALSE FRONT ENDS.—To decrease the inside length of the front end a circular plate was fastened on the inside, 4½ inches, 8 7-16 inches and 20 inches, respectively, from the forward end. (Fig. 39.) All such work was made practically tight. The experiments involving the use of this apparatus are designated elsewhere as Series 15.

23. DRAFT PIPES.—Draft pipes 13 inches, 15 inches and 17 inches in diameter were employed (Figs. 40 and 41). The base of each draft pipe was 18 inches in height. Pipes of greater height were obtained by adding 6-inch increments, by means of which a total height for any diameter of 48 inches could be secured.

An arrangement shown in Fig. 42 was employed for supporting the draft pipes at different heights. A horizontal shaft through the smoke box was provided with bearings attached to the shell of the smoke box. The outside end of this shaft was fitted with a crank by which it could be rotated or secured. Inside of the smoke box it carried two arms, the outer ends of which were attached by links to the draft pipes. By means of the outside crank the horizontal shaft could be turned and the draft pipes made to assume any desired position vertically. Two arms extending from the draft pipes with fingers fitting vertical rods acted as guides for the draft pipes. Where two draft pipes were employed, one was fixed to the vertical guides and the other supported by means of the arrangement described. The experiments involving the use of this apparatus are designated elsewhere as Series 16 to 87, inclusive.

24. BACK DRAFT FLUE.—In order to keep the front end free from gases while the experimental equipment was being changed, a sheet-iron pipe was employed leading from one of the fire doors to the outside of the building. By use of a steam jet a draft was created through this pipe from the front end. This arrangement was similar to that used by Mr. Quayle in the North-Western tests of experimental exhaust pipes. This apparatus was used throughout the tests.

25. DIAPHRAGM ALTERATIONS.—The extended diaphragm of the normal equipment of the front end (Fig. 43) of locomotive 3929 was removed

during the tests and one of simpler form substituted. In determining the area under the shorter diaphragm, an effort was made to have the resistance of the shorter diaphragm equal that of the longer one. Experiments showed that this result was approximately secured when the area of opening was 90 square inches (Fig. 44). The extended diaphragm was used in experiments designated elsewhere as Series 1, 2 and 10. The shorter diaphragm was used in all other experiments.

26. THE TEST.—In running a test the engine, after having been thoroughly warmed by preliminary running, was started and the boiler pressure allowed to exceed slightly that at which a reading was to be taken. The desired speed and throttle opening were then secured and maintained, the pressure meantime being allowed to slowly fall. As the boiler pressure approached the desired limit, two blasts of the whistle were given as a warning, and later readings were taken in response to a single blast of the whistle. The readings for all tests were as follows:

Speed, miles per hour.
Boiler pressure, pounds.
Pressure in fire box.
Pressure in front end behind diaphragm.
Pressure in front end in front of diaphragm.
Pressure in exhaust steam cavity.

With each arrangement of the front end, tests were in the earlier portion of the work, made with a cut-off of twenty-three per cent, the locomotive running at 40, 50 and 60 miles an hour, respectively, also, at a constant speed of 50 miles an hour with a cut-off of eighteen, twenty-three and twenty-eight per cent. For all of these tests, the steam pressure was 180 pounds and the throttle wide open. After the work had been well started upon this plan, some members of the committee thought it desirable that tests be also made at very slow speeds and, in compliance with this view, there were added tests at 40 and 80 revolutions under a partially open throttle, and still later, when sufficient data had been accumulated to confirm a conclusion based upon earlier tests that the efficiency of the front end was independent of the condition of running, certain of these conditions were omitted, the progress of the work being thereby hastened.

A set of typical indicator diagrams representing the various conditions of running is presented as Figs. 45 to 51, inclusive.

A sample log as developed in the laboratory as the work proceeded, is shown by Fig. 52. This gives the data obtained from tests of a stack 21 + 29 — 24 used in conjunction with a 24-inch false top and test diaphragm. The significance of the several columns is as follows: The first gives the number of the observation; second, the speed of the engine in revolutions per minute; third, the speed of the engine in miles per hour; fourth, the position of the reverse lever; fifth, the boiler pressure when running at full throttle; sixth, the dry-pipe pressure when running with the throttle partly closed. The seventh, eighth and ninth give the

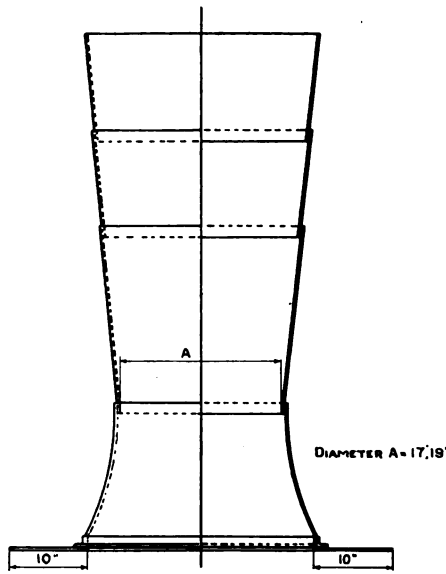

FIG. 35. SPECIAL INSIDE STACK.

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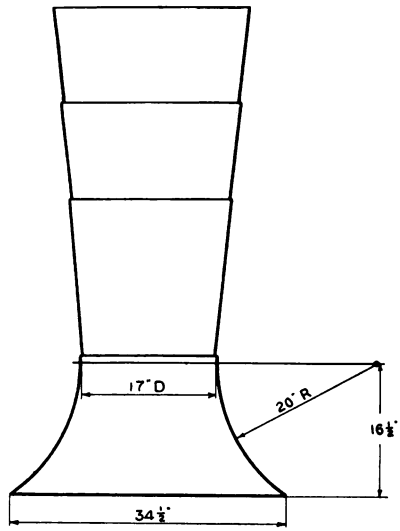

FIG. 36. SPECIAL INSIDE STACK.

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PURDUE UNIVERSITY.

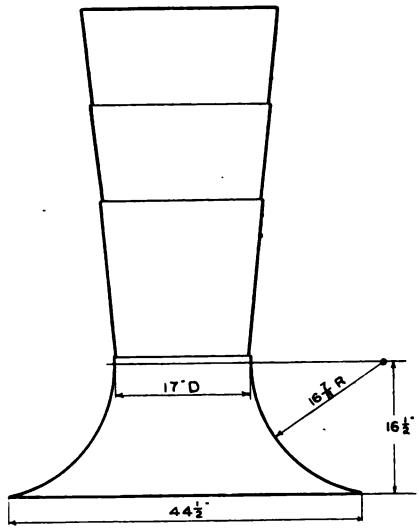

FIG. 37. SPECIAL INSIDE STACK.

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PURDUE UNIVERSITY.

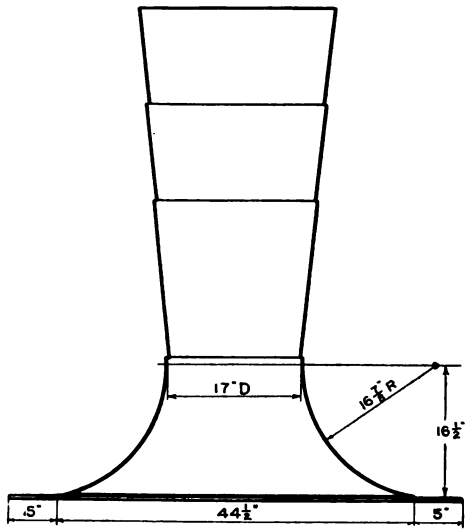

FIG. 38. SPECIAL INSIDE STACK.

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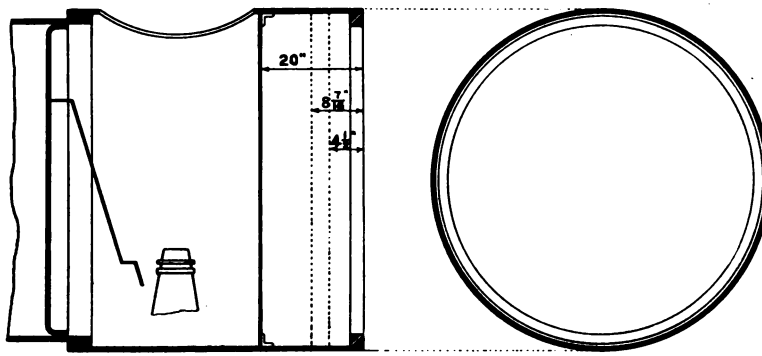

FIG. 39. FALSE FRONT END.

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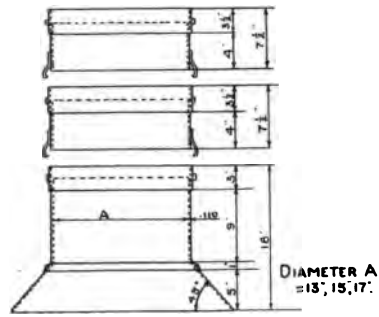

FIG. 40. DRAFT PIPES.

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FIG. 41. DRAFT PIPES.

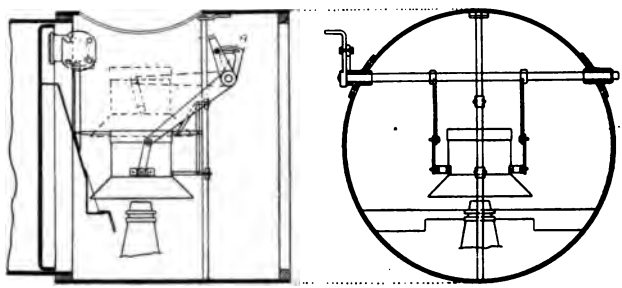

FIG. 42. ARRANGEMENT FOR SETTING DRAFT PIPES.

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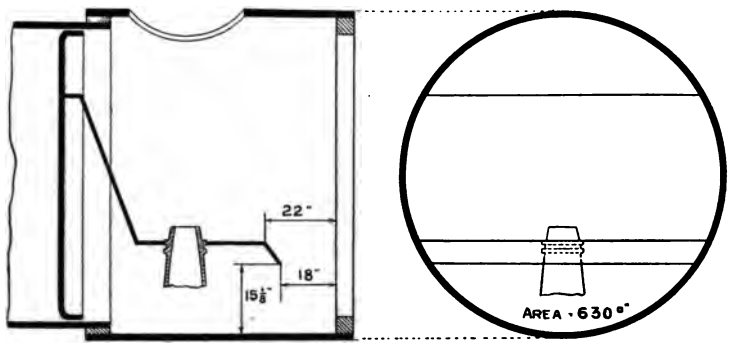

FIG. 43 ARRANGEMENT OF NORMAL DIAPHRAGM.

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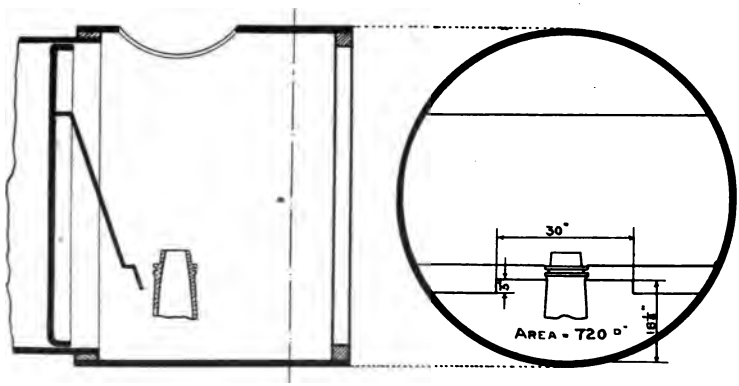

FIG. 44. ARRANGEMENT OF TEST DIAPHRAM.

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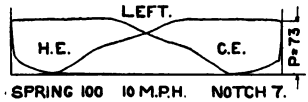
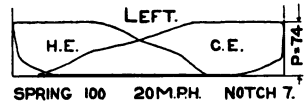
PURDUE UNIVERSITY.

Fig. 45



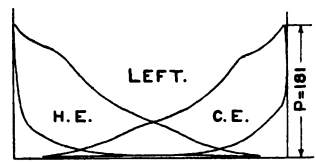
SPRING 100 10 M.P.H. NOTCH 7.

Fig. 46



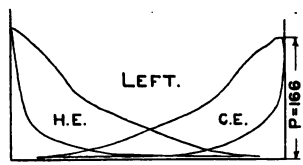
SPRING 100 20 M.P.H. NOTCH 7.

Fig. 47



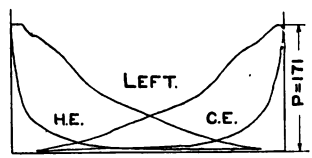
SPRING 100. 40 M.P.H. NOTCH 1.

Fig. 48



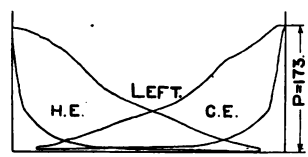
SPRING 100 50 M.P.H. NOTCH 0

Fig. 49



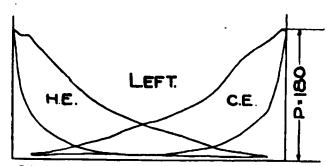
SPRING 100 50 M.P.H. NOTCH 1.

Fig. 50



SPRING 100 50 M.P.H. NOTCH 2.

Fig. 51



SPRING 100 60 M.P.H. NOTCH 1

TYPICAL INDICATOR DIAGRAMS.

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RUNNING LOG.

STACK 21+29-24. FALSE TOP. TEST DIAPHRAGM.

OBSERVERS } — DATE JAN 19, 1906.

NO.	R.P.M.	M.P.H.	NOTCH.	STEAM PRESSURE	DRY PIPE PRESSURE	DRAFT INCHES OF WATER: FIRE BOX	BEHIND DIAPHRAGM	SMOKE BOX	BACK PRESSURE POUNDS PER SQ. IN.: Hg	H_2O	CORRECTED PRESSURE
1		40	1	180		.72	2.10	3.80	3.60	.86	2.74
2		50	1	"		.76	2.50	4.60	4.00	.56	3.44
3		60	1	"		.83	2.70	5.40	4.60	.47	4.13
4		40	1	"		.69	1.80	3.40	2.80	.55	2.25
5		50	1	"		.78	2.40	4.50	3.80	.52	3.28
6		60	1	"		.81	2.60	5.00	4.50	.71	3.79
7		60	1	"		.80	2.70	5.30	4.70	.59	4.11
8		40	1	"		.65	1.90	3.30	3.10	.74	2.36
9	40		7		60	.07	.25	.40			.15
10	40		7		80	.12	.40	.60			.18
11	40		7		80	.12	.35	.60			.17
12	80		7		60	.26	.45	.75			.26
13	80		7		60	.24	.55	.80			.30
14	80		7		80	.44	.85	1.55			.67
15	80		7		80	.42	.90	1.60			.74
TOTAL.											
AVERAGE.											

FIG. 52.

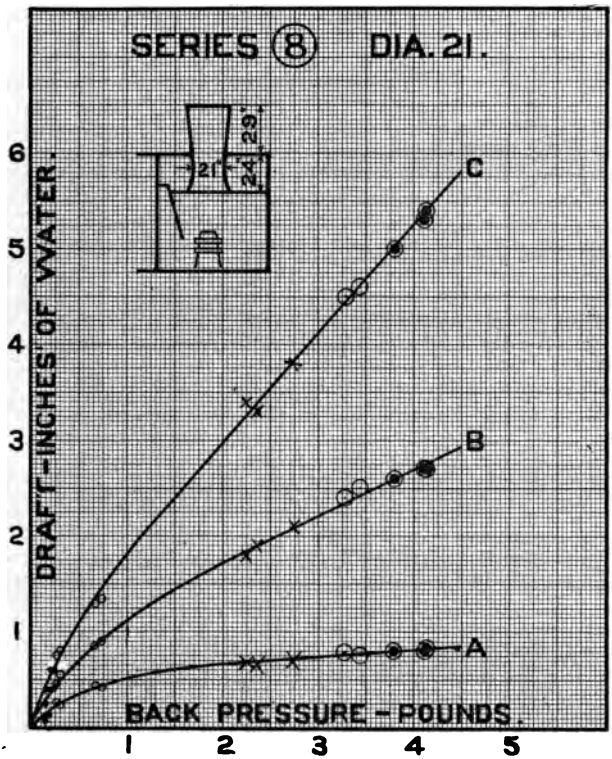

FIG. 53.

X = 40 MILES PER HOUR
⊙ = 50 " " "
◉ = 60 " " "
• = 40 REV. PER MINUTE
○ = 80 " " "

draft in inches of water, in the fire box, behind the diaphragm and in the smoke box, respectively. Columns 10, 11 and 12 give the readings of the back pressure gauge, 10 being the reading of the mercury side of the gauge, 11 the reading of the water side of the gauge, and twelve the correct pressure as derived from 10 and 11.

A complete statement of the several arrangements of the front end and of all the conditions under which they were tested, is set forth as follows:

OUTSIDE STACKS.

NOTE.—In the designation of stacks throughout this exhibit the first term is the diameter, the second the height outside of the smoke box, and the third the penetration into the smoke box, all expressed in inches.

	Number of Test.	Stack.
SERIES 1.—Diaphragm as originally arranged in locomotive.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	1	15 + 29 − 0
b. Speed 50 M.P.H., cut-off 18, 23 and 28%	2	17 + 29 − 0
c. Speed 60 M.P.H., cut-off 23%.....	3	18 + 29 − 0
Steam pressure 180 pounds.....	4	19 + 29 − 0
	5	21 + 29 − 0
SERIES 2.—Original diaphragm retained, draft pipes removed.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	6	15. + 29 − 0
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	7	17 + 29 − 0
c. Speed 60 M.P.H., cut-off 23%.....	8	18 + 29 − 0
Steam pressure 180 pounds.....	9	19 + 29 − 0
	10	21 + 29 − 0
SERIES 3.—Extension diaphragm plate removed. Similar draft conditions secured by altering diaphragm plate proper.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	11	15 + 29 − 0
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	12	17 + 29 − 0
c. 60 M.P.H., cut-off 23%.....	13	18 + 29 − 0
d. 40 and 80 R.P.M., cut-off 50%.....	14	19 + 29 − 0
NOTE.—Item "d" applies to tests 16 and 17 only.	15	21 + 29 − 0
Steam pressure 180 pounds.....	16	23 + 29 − 0
	17	25 + 29 − 0
SERIES 4.—Modified diaphragm. Diameter of stack variable, height 47".		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	18	15 + 47 − 0
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	19	17 + 47 − 0
c. Speed 60 M.P.H., cut-off 23%.....	20	19 + 47 − 0
Steam pressure 180 pounds.....	21	21 + 47 − 0

	Number of Test.	Stack.
SERIES 5.—Diameter of stack variable. Height outside 29″. Inside length 12″.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	22	15 + 29 − 12
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	23	17 + 29 − 12
c. Speed 60 M.P.H., cut-off 23%.....	24	19 + 29 − 12
Steam pressure 180 pounds.....	25	21 + 29 − 12
SERIES 6.—Diameter of stack variable. Height outside 29″. Inside length 24″.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	26	15 + 29 − 24
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	27	17 + 29 − 24
c. Speed 60 M.P.H., cut-off 23%.....	28	19 + 29 − 24
Steam pressure 180 pounds.....	29	21 + 29 − 24
SERIES 7.—Diameter of stack variable. Height outside 29″. Inside length 26″.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....	30	15 + 29 − 36
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	31	17 + 29 − 36
c. Speed 60 M.P.H., cut-off 23%.....	32	19 + 29 − 36
Steam pressure 180 pounds.....	33	21 + 29 − 36

FALSE TOPS.

SERIES 8.—Diameter of stack variable. Height outside 29″. Inside length 24″. Modified diaphragm.		
CONDITIONS OF TESTS:		
a. Speed 40 M.P.H., cut-off 23%.....		
b. Speed 50 M.P.H., cut-off 18, 23 and 28%.	34	15 + 29 − 24
c. Speed 60 M.P.H., cut-off 23%.....	35	17 + 29 − 24
d. Steam pressure 180 pounds.....	36	15 + 29 − 24
NOTE.—Items a, b and c refer to tests 34 and 35 only.	37	17 + 29 − 24
	38	19 + 29 − 24
e. Speed 40, 50 and 60 M.P.H., cut-off 23% Steam pressure 180 pounds.....	39	21 + 29 − 24
f. Speed 40 and 80 R.P.M., cut-off 50%.... Steam pressure 60 and 80 pounds.....		
NOTE.—Items "f" and "g" refer to tests 36, 37, 38 and 39 only.		
SERIES 9.—Diameter of stack variable. Height of stack 29″. Inside length 36″. Modified diaphragm.		
CONDITIONS OF TESTS:		
a. Speed 40, 50 and 60 M.P.H., cut-off 23% Steam pressure 180 pounds.....	40	15 + 29 − 36
	41	17 + 29 − 36
	42	19 + 29 − 36
	43	21 + 29 − 36
b. Speed 40 and 80 R.P.M., cut-off 50%.... Steam pressure 60 and 80 pounds.....		

	Number of Test.	Stack.
SERIES 10.—Best arrangement of false top and inside stack. Original diaphragm. CONDITIONS OF TESTS: a. Speed 40, 50 and 60 M.P.H., cut-off 23% Steam pressure 180 pounds. b. Speed 40 and 80 R.P.M., cut-off 50%. Steam pressure 60 and 80 pounds.	44	17 + 29 − 24

SPECIAL STACKS.

SERIES 11.—Diameter of stack variable. 10″ circular plate substituted for false top. CONDITIONS OF TESTS: a. Speed 40, 50 and 60 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 40 and 80 R.P.M., cut-off 50%. Steam pressure 60 and 80 pounds.	45 46	17 + 29 − 24 19 + 29 − 24
SERIES 12.—Inside stack having 44½″ diameter flared base. Inside length of stack variable. CONDITIONS OF TESTS: a. Speed 40, 50 and 60 M.P.H. cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50% Steam pressure 60 and 80 pounds. c. Speed 40 R.P.M., cut-off 50%. Steam pressure 60 pounds.	47 48	17 + 29 − 24 17 + 29 − 36
SERIES 13.—Inside stack having 44½″ diameter flared base and 6″ circular plate on base. CONDITIONS OF TESTS: a. Speed 40, 50 and 60 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. 80 R.P.M., cut-off 50%. Steam pressure 60 and 80 pounds. c. 40 R.P.M., cut-off 50%. Steam pressure 60 pounds.	49	17 + 29 − 24
SERIES 14.—Inside stack having 34½″ diameter flared base. Inside length of stack variable. CONDITIONS OF TESTS: a Speed 40, 50 and 60 M.P.H., cut-off 23%. b. Steam pressure 180 pounds.	50 51	17 + 29 − 24 17 + 29 − 36

Shortened Front-End (Series 15), Tests 52-54.

SERIES 15.—Inside stack having 34½″ diameter flared base. False front-end in boiler. Position of false front-end variable, 4½, 8⅞, 20″. a. Speed 40, 50 and 60 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 and 80 pounds. c. Speed 40 R.P.M., cut-off 50%. Steam pressure 60 pounds. NOTE.—Items "b" and "c" refer to tests Nos. 52 and 53 only.	52 53 54	17 + 29 − 24 17 + 29 − 24 17 + 29 − 24

SINGLE DRAFT PIPES.

NOTE.—In the designation of single draft pipes throughout this exhibit the first term represents the diameter of the draft pipe, the second the height of the base above the exhaust tip, and the third the height of the pipe.

	Number of Test.	Stack.
SERIES 16.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	55	13 + 0 + 18
	56	13 + 1 + 18
	57	13 + 2 + 18
	58	13 + 4 + 18
	59	13 + 8 + 18
	60	13 + 16 + 18
SERIES 17.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	61	13 + 0 + 24
	62	13 + 1 + 24
	63	13 + 2 + 24
	64	13 + 4 + 24
	65	13 + 8 + 24
	66	13 + 16 + 24
SERIES 18.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	67	13 + 0 + 30
	68	13 + 1 + 30
	69	13 + 2 + 30
	70	13 + 4 + 30
	71	13 + 8 + 30
	72	13 + 16 + 30
SERIES 19.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	73	13 + 0 + 36
	74	13 + 1 + 36
	75	13 + 2 + 36
	76	13 + 4 + 36
	77	13 + 8 + 36
SERIES 20.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 H.P.M., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	78	13 + 0 + 42
	79	13 + 1 + 42
	80	13 + 2 + 42
	81	13 + 4 + 42
SERIES 21.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	82	13 + 0 + 48

	Number of Test.	Stack.
SERIES 22.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 50 R.P.M. cut-off 50%. Steam pressure 80 pounds.	83	13 + 0 + 18
	84	13 + 1 + 18
	85	13 + 2 + 18
	86	13 + 4 + 18
	87	13 + 8 + 18
	88	13 + 16 + 18
SERIES 23.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	89	13 + 0 + 24
	90	13 + 1 + 24
	91	13 + 2 + 24
	92	13 + 4 + 24
	93	13 + 8 + 24
	94	13 + 16 + 24
SERIES 24.—Stack 19 + 29 0. − Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	95	13 + 0 + 30
	96	13 + 1 + 30
	97	13 + 2 + 30
	98	13 + 4 + 30
	99	13 + 8 + 30
	100	13 + 16 + 30
SERIES 25.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	101	13 + 0 + 36
	102	13 + 1 + 36
	103	13 + 2 + 36
	104	13 + 4 + 36
	105	13 + 8 + 36
SERIES 26.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	106	13 + 0 + 42
	107	13 + 1 + 42
	108	13 + 2 + 42
	109	13 + 4 + 42
SERIES 27.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	110	13 + 0 + 48
SERIES 28.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H. cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	111	13 + 0 + 18
	112	13 + 1 + 18
	113	13 + 2 + 18
	114	13 + 4 + 18
	115	13 + 8 + 18
	116	13 + 16 + 18

	Number of Test.	Stack.
SERIES 29.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P M., cut-off 50%. Steam pressure 80 pounds.	117	13 + 0 + 24
	118	13 + 1 + 24
	119	13 + 2 + 24
	120	13 + 4 + 24
	121	13 + 8 + 24
	122	13 + 16 + 24
SERIES 30.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P M., cut-off 50%. Steam pressure 80 pounds.	123	13 + 0 + 30
	124	13 + 1 + 30
	125	13 + 2 + 30
	126	13 + 4 + 30
	127	13 + 8 + 30
	128	13 + 16 + 30
SERIES 31.—Stack 23 + 29 − 0. Variable—Height of draft pipes above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P M. cut-off 50%. Steam pressure 80 pounds.	129	13 + 0 + 36
	130	13 + 1 + 36
	131	13 + 2 + 36
	132	13 + 4 + 36
	133	13 + 8 + 36
SERIES 32.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P M., cut-off 50%. Steam pressure 80 pounds.	134	13 + 0 + 42
	135	13 + 1 + 42
	136	13 + 2 + 42
	137	13 + 4 + 42
SERIES 33.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	138	13 + 0 + 48
SERIES 34.—Stack 15 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	139	15 + 0 + 18
	140	15 + 1 + 18
	141	15 + 2 + 18
	142	15 + 4 + 18
	143	15 + 8 + 18
	144	15 + 16 + 18
SERIES 35.—Stack 15 + 29 − 0. Variable—Height of draft pipes above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H. cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	145	15 + 0 + 24
	146	15 + 1 + 24
	147	15 + 2 + 24
	148	15 + 4 + 24
	149	15 + 8 + 24
	150	15 + 16 + 24

	Number of Test.	Stack.
SERIES 36.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	151	15 + 0 + 30
	152	15 + 1 + 30
	153	15 + 2 + 30
	154	15 + 4 + 30
	155	15 + 8 + 30
	156	15 + 16 + 30
SERIES 37.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	157	15 + 0 + 36
	158	15 + 1 + 36
	159	15 + 2 + 36
	160	15 + 4 + 36
	161	15 + 8 + 36
SERIES 38.—Stack 15 + 29 − 0. Variable— Height of draft pipes above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	162	15 + 0 + 42
	163	15 + 1 + 42
	164	15 + 2 + 42
	165	15 + 4 + 42

	Number of Tests.	Draft Pipes.
SERIES 39.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M., cut-off 50%..... Steam pressure 80 pounds.....	166	15 + 0 + 48
SERIES 40.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a Speed 50 M.P.H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P.M. cut-off 50%..... Steam pressure 80 pounds.....	167	15 + 0 + 18
	168	15 + 1 + 18
	169	15 + 2 + 18
	170	15 + 4 + 18
	171	15 + 8 + 18
	172	15 + 16 + 18
SERIES 41.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip..... CONDITIONS OF TESTS: a. Speed 50 M.P H., cut-off 23%..... Steam pressure 180 pounds..... b. Speed 80 R.P M., cut-off 50%..... Steam pressure 80 pounds.....	173	15 + 0 + 24
	174	15 + 1 + 24
	175	15 + 2 + 24
	176	15 + 4 + 24
	177	15 + 8 + 24
	178	15 + 16 + 24

	Number of Tests.	Draft Pipes.
SERIES 42.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	179	15 + 0 + 30
	180	15 + 1 + 30
	181	15 + 2 + 30
	182	15 + 4 + 30
	183	15 + 8 + 30
	184	15 + 16 + 30
SERIES 43.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	185	15 + 0 + 36
	186	15 + 1 + 36
	187	15 + 2 + 36
	188	15 + 4 + 36
	189	15 + 8 + 36
SERIES 44.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	190	15 + 0 + 42
	191	15 + 1 + 42
	192	15 + 2 + 42
	193	15 + 4 + 42
SERIES 45.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	194	15 + 0 + 48
SERIES 46.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	195	15 + 0 + 18
	196	15 + 1 + 18
	197	15 + 2 + 18
	198	15 + 4 + 18
	199	15 + 8 + 18
	200	15 + 16 + 18
SERIES 47.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	201	15 + 0 + 24
	202	15 + 1 + 24
	203	15 + 2 + 24
	204	15 + 4 + 24
	205	15 + 8 + 24
	206	15 + 16 + 24
SERIES 48.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	207	15 + 0 + 30
	208	15 + 1 + 30
	209	15 + 2 + 30
	210	15 + 4 + 30
	211	15 + 8 + 30
	212	15 + 16 + 30

	Number of Tests.	Draft Pipes.
SERIES 49.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	213	15 + 0 + 36
	214	15 + 1 + 36
	215	15 + 2 + 36
	216	15 + 4 + 36
	217	15 + 8 + 36
SERIES 50.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	218	15 + 0 + 42
	219	15 + 1 + 42
	220	15 + 2 + 42
	221	15 + 4 + 42
SERIES 51.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	222	15 + 0 + 48
SERIES 52.—Stack 15 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	223	17 + 0 + 18
	224	17 + 1 + 18
	225	17 + 2 + 18
	226	17 + 4 + 18
	227	17 + 8 + 18
	228	17 + 16 + 18
SERIES 53.—Stack 15 + 29 − 0. Variable—Height of draft pipes above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	229	17 + 0 + 24
	230	17 + 1 + 24
	231	17 + 2 + 24
	232	17 + 4 + 24
	233	17 + 8 + 24
	234	17 + 16 + 24
SERIES 54.—Stack 15 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	235	17 + 0 + 30
	236	17 + 1 + 30
	237	17 + 2 + 30
	238	17 + 4 + 30
	239	17 + 8 + 30
	240	17 + 16 + 30
SERIES 55.—Stack 15 + 29 − 0. Variable—Height of draft pipe above exhaust tip: CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	241	17 + 0 + 36
	242	17 + 1 + 36
	243	17 + 2 + 36
	244	17 + 4 + 36
	245	17 + 8 + 36

	Number of Tests.	Draft Pipes.
SERIES 56.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	246	17 + 0 + 42
	247	17 + 1 + 42
	248	17 + 2 + 42
	249	17 + 4 + 42
SERIES 57.—Stack 15 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	250	17 + 0 + 48
SERIES 58.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	251	17 + 0 + 18
	252	17 + 1 + 18
	253	17 + 2 + 18
	254	17 + 4 + 18
	255	17 + 8 + 18
	256	17 + 16 + 18
SERIES 59.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	257	17 + 0 + 24
	258	17 + 1 + 24
	259	17 + 2 + 24
	260	17 + 4 + 24
	261	17 + 8 + 24
	262	17 + 16 + 24
SERIES 60.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	263	17 + 0 + 30
	264	17 + 1 + 30
	265	17 + 2 + 30
	266	17 + 4 + 30
	267	17 + 8 + 30
	268	17 + 16 + 30
SERIES 61.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	269	17 + 0 + 36
	270	17 + 1 + 36
	271	17 + 2 + 36
	272	17 + 4 + 36
	273	17 + 8 + 36
SERIES 62.—Stack 19 + 29 − 0. Variable— Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	274	17 + 0 + 42
	275	17 + 1 + 42
	276	17 + 2 + 42
	277	17 + 4 + 42

	Number of Tests.	Draft Pipes.
SERIES 63.—Stack 19 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds	278	17 + 0 + 48
SERIES 64.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	279	17 + 0 + 18
	280	17 + 1 + 18
	281	17 + 2 + 18
	282	17 + 4 + 18
	283	17 + 8 + 18
	284	17 + 16 + 18
SERIES 65.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	285	17 + 0 + 24
	286	17 + 1 + 24
	287	17 + 2 + 24
	288	17 + 4 + 24
	289	17 + 8 + 24
	290	17 + 16 + 24
SERIES 66.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	291	17 + 0 + 30
	292	17 + 1 + 30
	293	17 + 2 + 30
	294	17 + 4 + 30
	295	17 + 8 + 30
	296	17 + 16 + 30
SERIES 67.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 80 pounds.	297	17 + 0 + 36
	298	17 + 1 + 36
	299	17 + 2 + 36
	300	17 + 4 + 36
	301	17 + 8 + 36
SERIES 68.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	302	17 + 0 + 42
	303	17 + 1 + 42
	304	17 + 2 + 42
	305	17 + 4 + 42
SERIES 69.—Stack 23 + 29 − 0. Variable—Height of draft pipe above exhaust tip. CONDITIONS OF TESTS: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 80 pounds.	306	17 + 0 + 48

DOUBLE DRAFT PIPES.

NOTE.—In the designation of double draft pipes, throughout this exhibit, the first term represents the diameter of the lower draft pipe, the second the diameter of the upper draft pipe, the third the height of the base of lower draft pipe above exhaust tip, and the fourth the height of the base of the upper draft pipe above the exhaust tip. The length of each draft pipe was 18 inches.

	Number of Tests.	Draft Pipes.
SERIES 70.—Stack 15 + 29 − 0. Variable—Height of upper draft pipe.		
CONDITIONS OF TESTS:		
a. Speed 50 M.P.H., cut-off 23%	307	13 + 15 + 0 + 18
Steam pressure 180 pounds.	308	13 + 15 + 0 + 20
b. Speed 80 R.P.M., cut-off 50%	309	13 + 15 + 0 + 22
Steam pressure 60 pounds.	310	13 + 15 + 0 + 24
NOTE.—Item "b" refers to tests Nos. 307, 308 and 309 only.		
SERIES 71.—Stack 15 + 29 − 0. Variable—Height of upper draft pipe.		
CONDITIONS OF TESTS:		
a. Speed 50 M.P.H., cut-off 23%	311	13 + 15 + 2 + 20
Steam pressure 180 pounds.	312	13 + 15 + 2 + 22
b. Speed 80 R.P.M., cut-off 50%	313	13 + 15 + 2 + 24
Steam pressure 60 pounds.		
NOTE.—Item "b" refers to test No. 312 only.		
SERIES 72.—Stack 15 + 29 − 0. Variable—Height of upper draft pipe.		
CONDITIONS OF TESTS:		
a. Speed 50 M.P.H., cut-off 23%	314	13 + 15 + 4 + 22
Steam pressure 180 pounds.	315	13 + 15 + 4 + 24
b. Speed 80 R.P.M., cut-off 50%		
Steam pressure 60 pounds.		
NOTE.—Item "b" refers to test No. 314 only.		
SERIES 73.—Stack 15 + 29 − 0. Variable—Height of upper draft pipes.		
CONDITIONS OF TESTS:	316	13 + 17 + 0 + 18
a. Speed 50 M.P.H., cut-off 23%	317	13 + 17 + 0 + 20
Steam pressure 180 pounds.	318	13 + 17 + 0 + 22
b. Speed 80 R.P.M., cut-off 50%	319	13 + 17 + 0 + 24
Steam pressure 60 pounds.		
SERIES 74.—Stack 15 + 29 − 0. Variable—Height of upper draft pipe.		
CONDITIONS OF TESTS:	320	13 + 17 + 2 + 20
S. Speed 50 M.P.H., cut-off 23%	321	13 + 17 + 2 + 22
ambm pressure 180 pounds.	322	13 + 17 + 2 + 24
papeeted 80 R.P.M., cut-off 50%		
S.Sre taessure 60 pounds.		

	Number of Tests.	Draft Pipes.
Series 75.—Stack 15 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	323	13 + 17 + 4 + 22
	324	13 + 17 + 4 + 24
Series 76.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H. cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	325	13 + 15 + 0 + 18
	326	13 + 15 + 0 + 20
	327	13 + 15 + 0 + 22
	328	13 + 15 + 0 + 24
Series 77.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	329	13 + 15 + 2 + 20
	330	13 + 15 + 2 + 22
	331	13 + 15 + 2 + 24
Series 78.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R. P. M., cut-off 50%. Steam pressure 60 pounds.	332	13 + 15 + 4 + 22
	333	13 + 15 + 4 + 24
Series 79.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M. cut-off 50%. Steam pressure 60 pounds.	334	13 + 17 + 0 + 18
	335	13 + 17 + 0 + 20
	336	13 + 17 + 0 + 22
	337	13 + 17 + 0 + 24
Series 80.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P H., cut-off 23%. Steam pressure 80 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	338	13 + 17 + 2 + 20
	339	13 + 17 + 2 + 22
	340	13 + 17 + 2 + 24
Series 81.—Stack 19 + 29 − 0. Variable—Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P H , cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P M., cut-off 50%. Steam pressure 60 pounds.	341	13 + 17 + 4 + 22
	342	13 + 17 + 4 + 24

	Number of Tests.	Draft Pipes.
Series 82.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	343	13 + 15 + 0 + 18
	344	13 + 15 + 0 + 20
	345	13 + 15 + 0 + 22
	346	13 + 15 + 0 + 24
Series 83.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	347	13 + 15 + 2 + 20
	348	13 + 15 + 2 + 22
	349	13 + 15 + 2 + 24
Series 84.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	350	13 + 15 + 4 + 22
	351	13 + 15 + 4 + 24
Series 85.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	352	13 + 17 + 0 + 18
	353	13 + 17 + 0 + 20
	354	13 + 17 + 0 + 22
	355	13 + 17 + 0 + 24
Series 86.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	356	13 + 17 + 2 + 20
	357	13 + 17 + 2 + 22
	358	13 + 17 + 2 + 24
Series 87.—Stack 23 + 29 − 0. Variable— Height of upper draft pipe. Conditions of Tests: a. Speed 50 M.P.H., cut-off 23%. Steam pressure 180 pounds. b. Speed 80 R.P.M., cut-off 50%. Steam pressure 60 pounds.	359	13 + 17 + 4 + 22
	360	13 + 17 + 4 + 24

27. PRESENTATION OF DATA.—From an elaborate study of experimental data derived from the earlier part of the work, it was found that the draft resulting from any arrangement of the front end had a definite relation to the back pressure, irrespective of the speed of the engine, cut-off or position of the throttle. This fact was emphasized in the report of the first tests upon the front end which were made at the Purdue laboratory, and was confirmed by the tests of 1903. The work of the present year adds additional evidence to its proof. Its significance is well shown by Fig. 53 upon which points obtained at various speeds and cut-off are plotted in terms of back pressure and draft. It will be seen that points obtained under any condition of running readily fall upon their appropriate curves. Any comparison designed to show the relative value of the different arrangements of the front end may therefore be safely based upon the draft resulting from its use in return for a given back pressure. Whether the back pressure results from high or low speed or from long or short cut-off is not important. Accepting this statement it was determined to make use of the principles involved in summarizing the results of the tests. To this end the draft values obtained from each arrangement as taken from laboratory logs such as shown by Fig. 52, have been plotted in terms of back pressure in the manner shown by Fig. 53. In this figure, however, care is taken to indicate the running conditions under which the different points were obtained, for the purpose of showing that whether the speed be high or low, the relation of draft to back pressure does not change. In the more general presentation of data, Figs. 54 to 181, the plotting is the same but no attempt is made to designate the running conditions under which the points were obtained. Upon all of these diagrams three curves appear, the first (A) representing the draft in the fire box; the second (B) the draft behind the diaphragm; and the third (C) the draft in the smoke box. The diagrams, Figs. 54 to 181, therefore, may be accepted as a complete record of all experimental results.

As a more convenient basis of comparison, there have been prepared for presentation in the committee's report (Figs. 10-19) a series of diagrams showing draft values (C) based upon a back pressure of 3½ pounds. These values were obtained from the diagrams, Fig. 54 to 181 of this report.

Respectfully submitted,

W. O. TEAGUE.

May, 1906.

Curve "A" in these figures represents the draft in the fire box; "B," the draft behind the diaphragm, and "C," the draft in the smoke box.

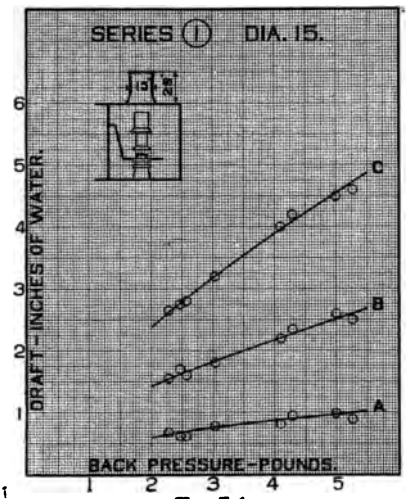

Fig. 54.

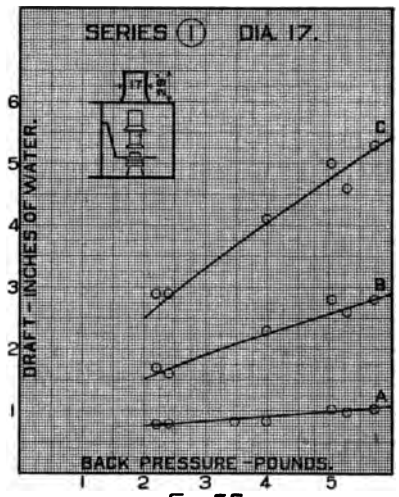

Fig. 55.

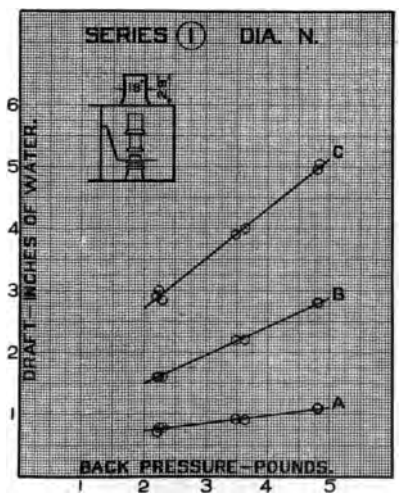

Fig. 56.

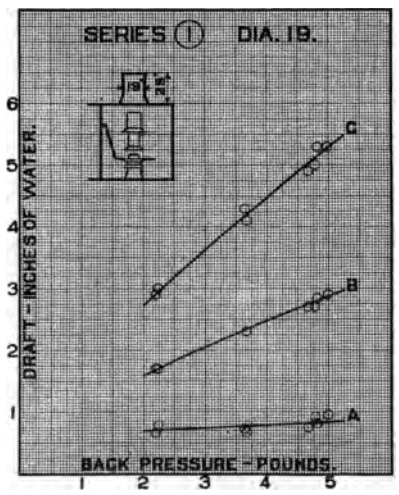

Fig. 57.

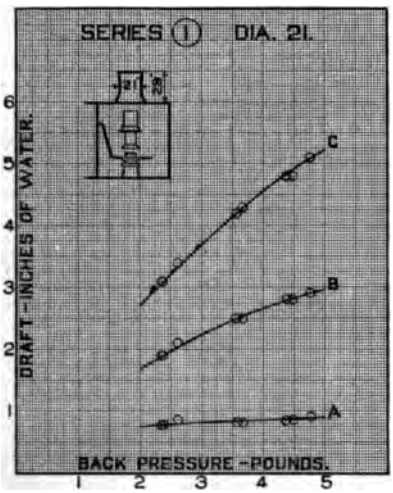

Fig. 58.

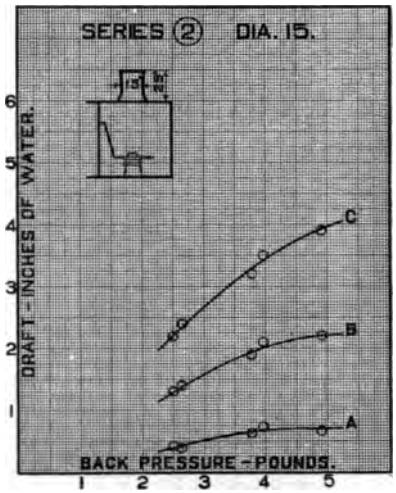

Fig. 59

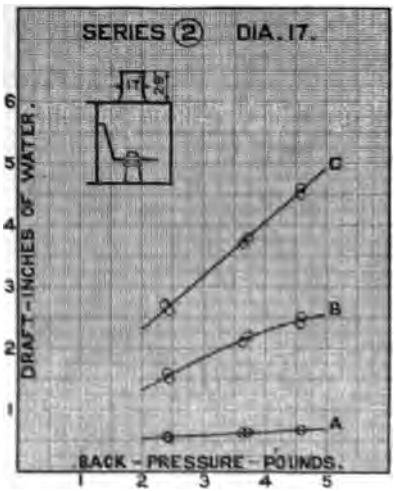

Fig. 60.

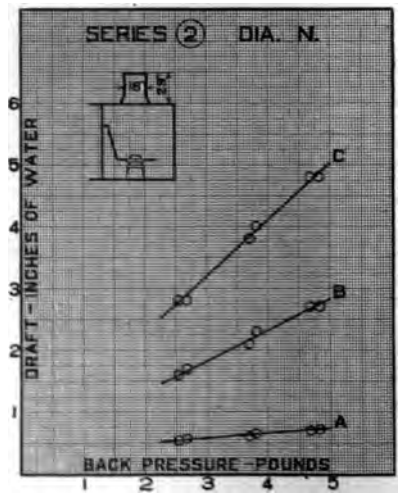

Fig. 61.

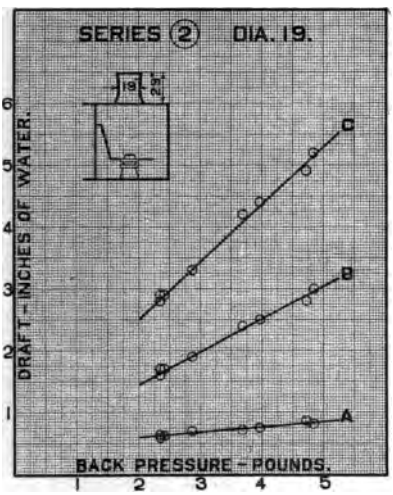

Fig. 62

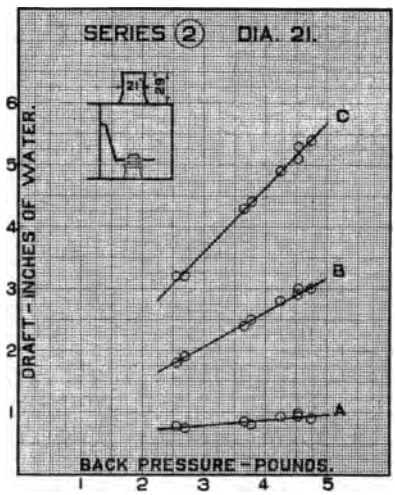

Fig. 63.

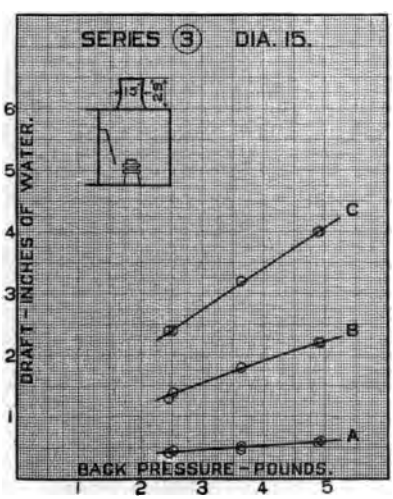

Fig. 64.

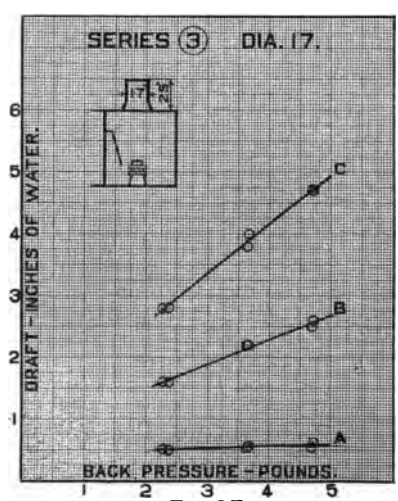

Fig. 65.

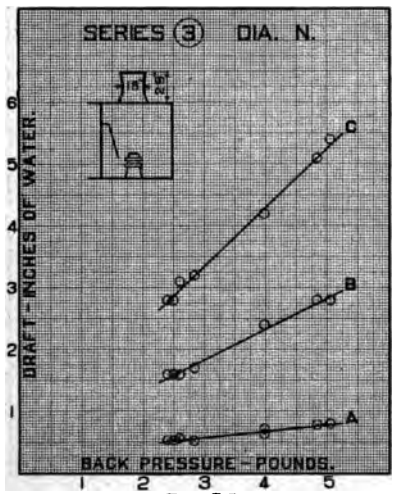

Fig. 66.

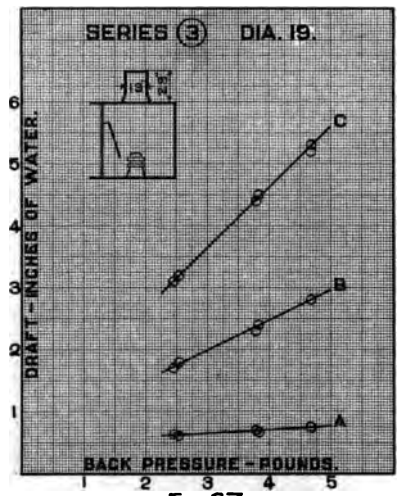

Fig. 67.

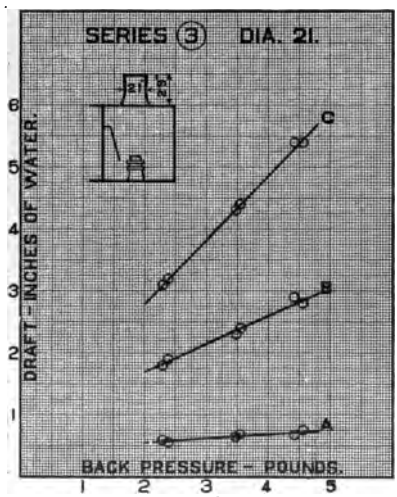

Fig. 68.

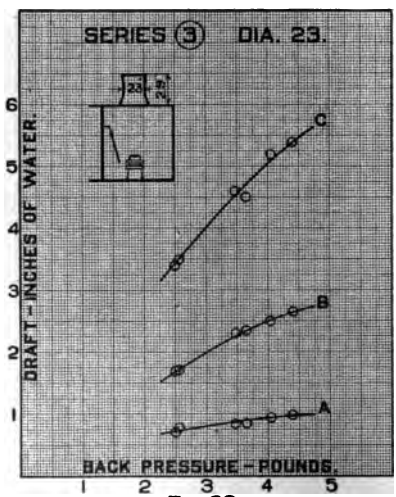

Fig. 69.

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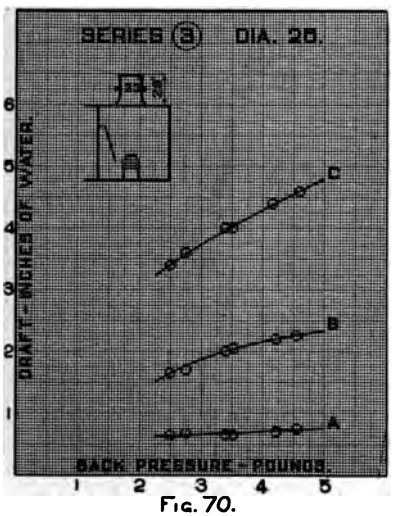

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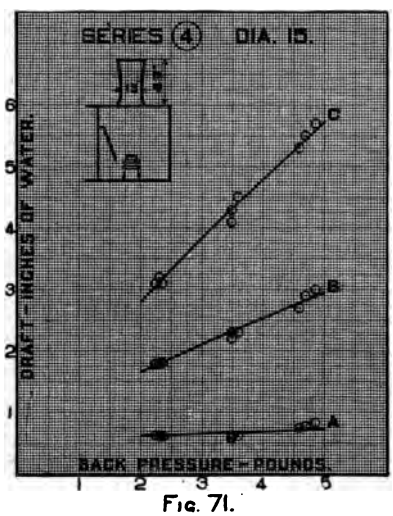

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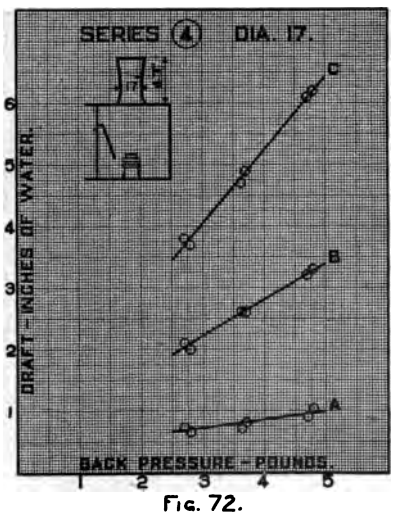

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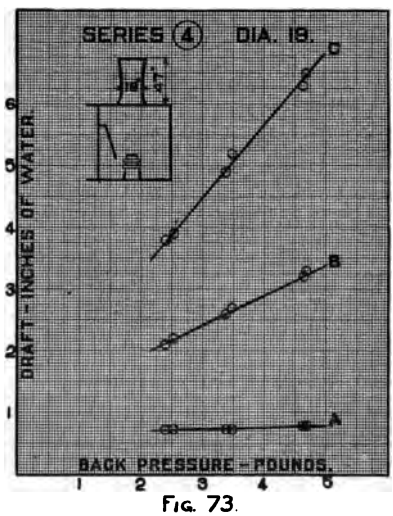

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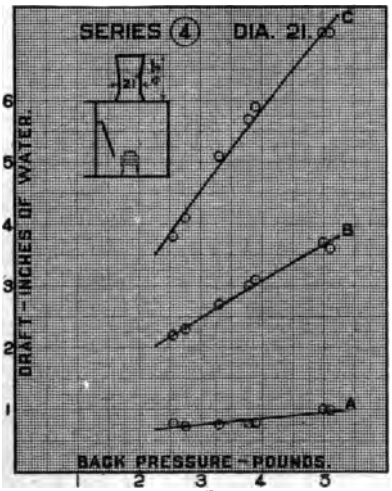

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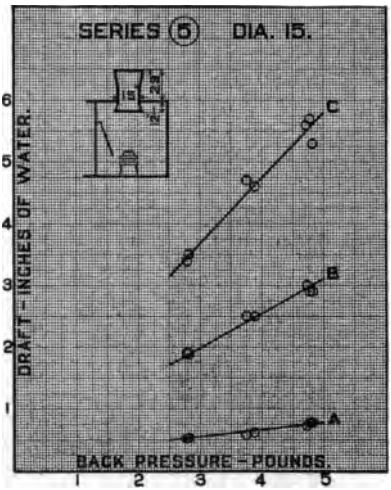
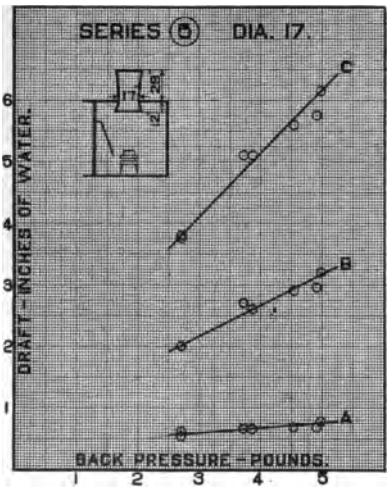


Fig. 75



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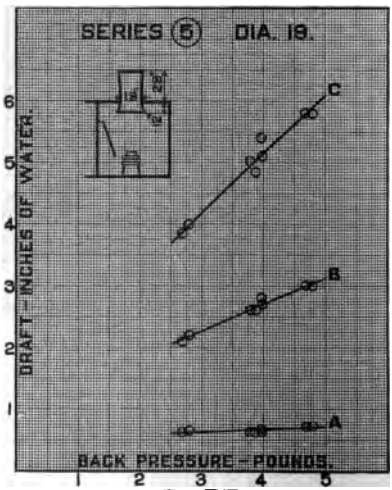

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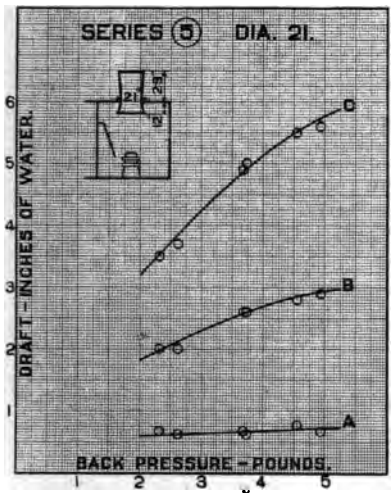

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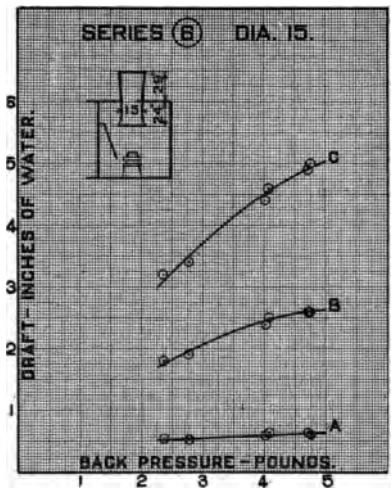

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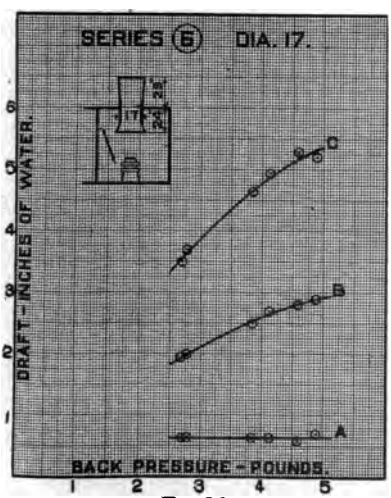

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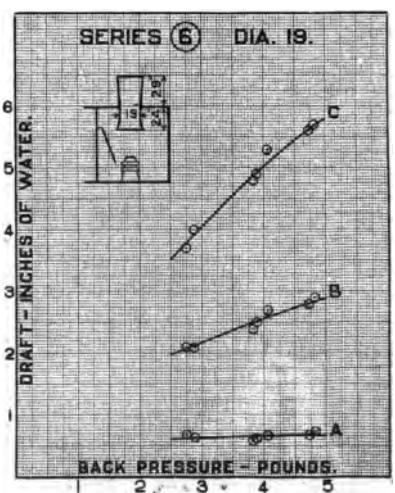

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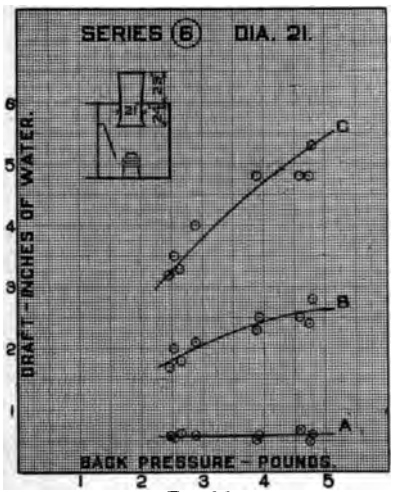

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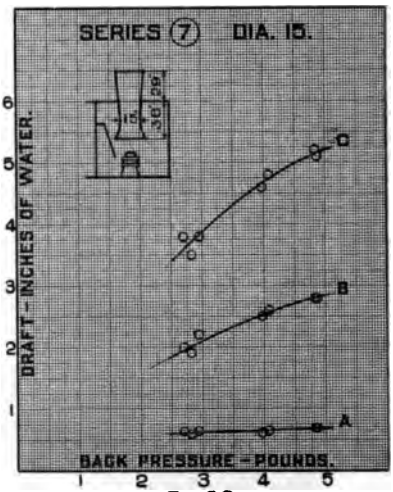

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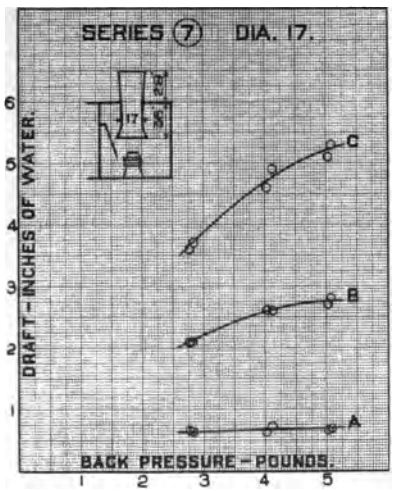
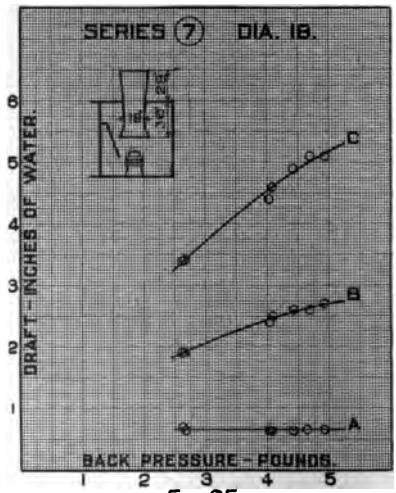


Fig 84



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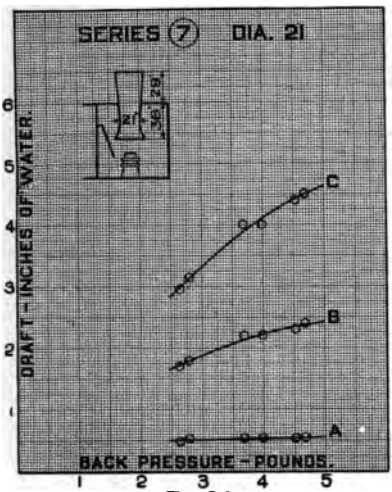

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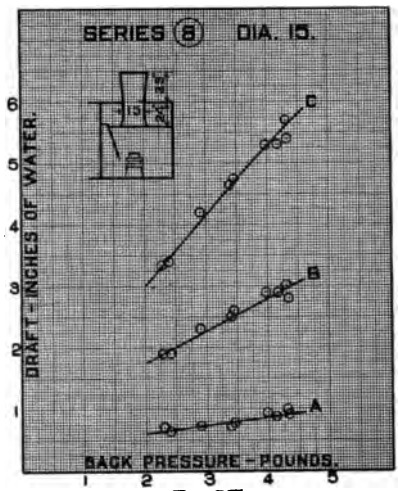

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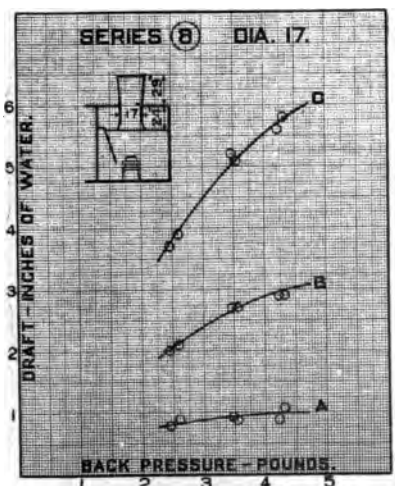

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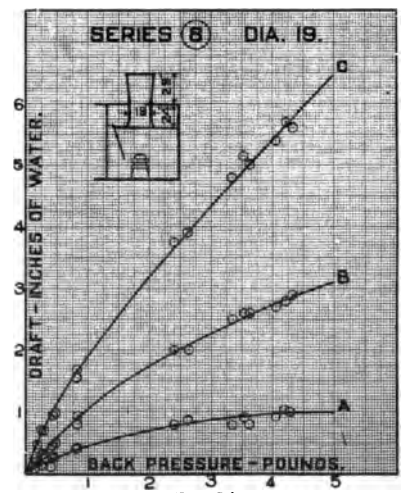


Fig. 89.

UofM

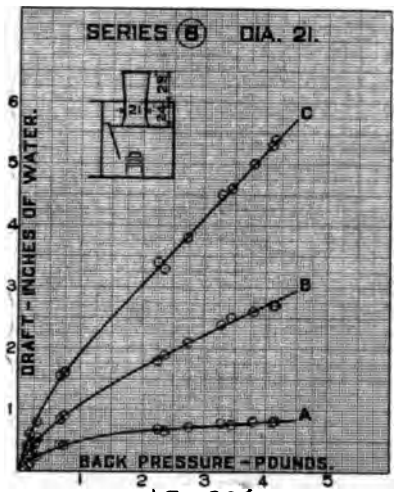
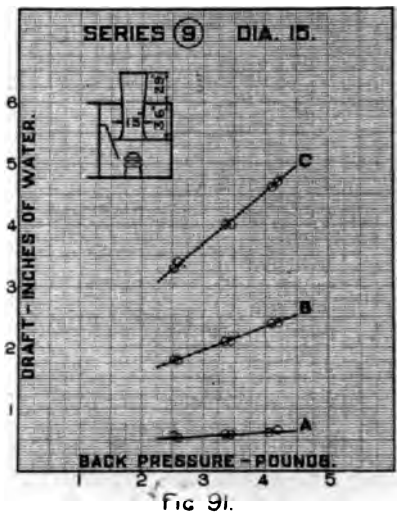

SERIES (8) DIA. 21.
DRAFT - INCHES OF WATER.
BACK PRESSURE - POUNDS.
A
B
C

Fig. 90.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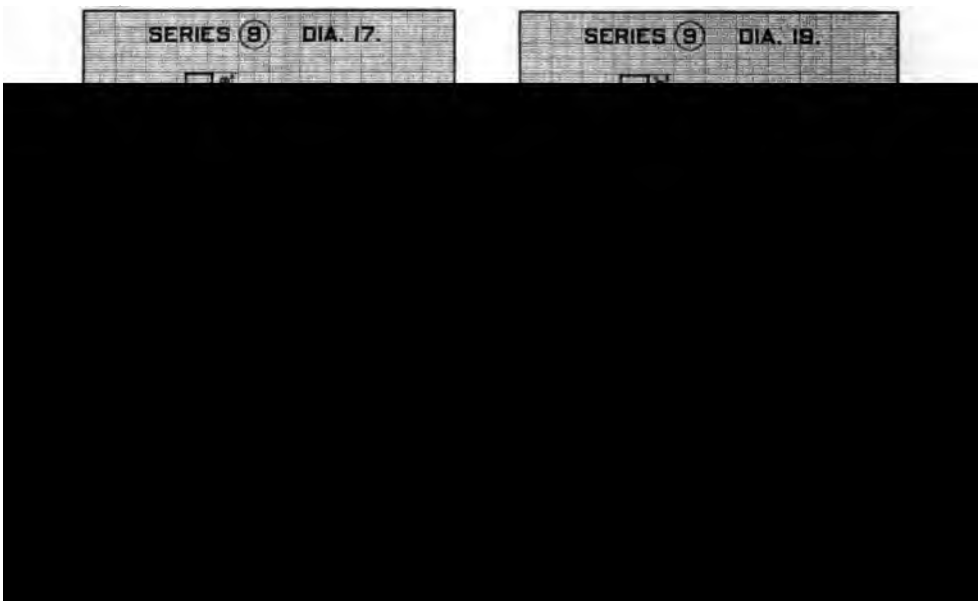
BACK PRESSURE - POUNDS.
A
B
C

Fig. 91.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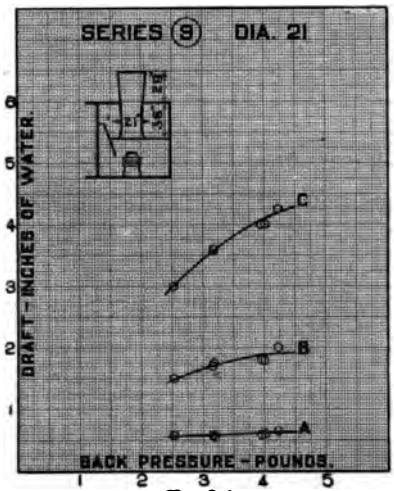
SERIES (9) DIA. 19.



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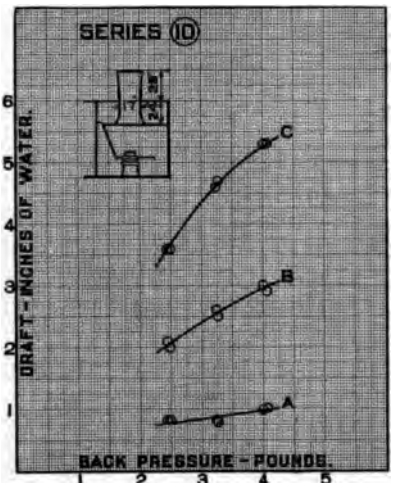

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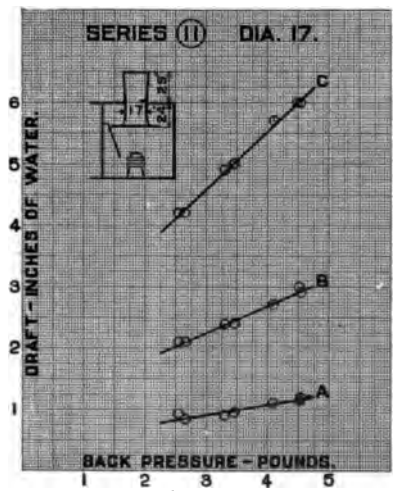

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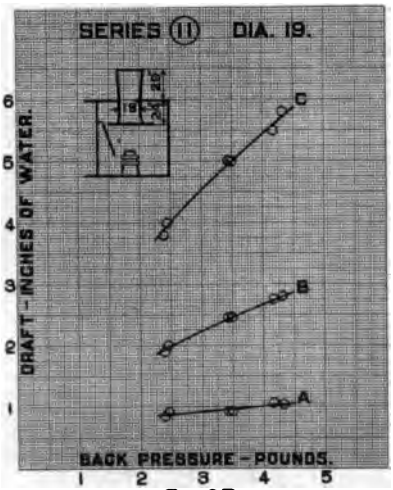
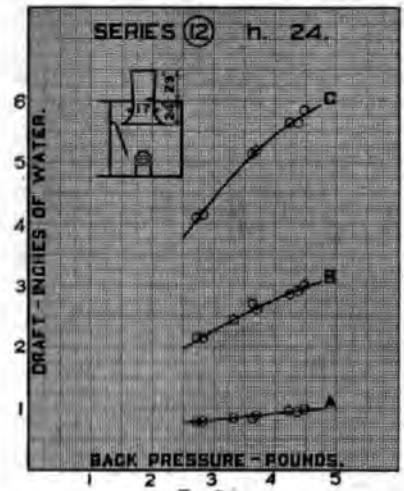
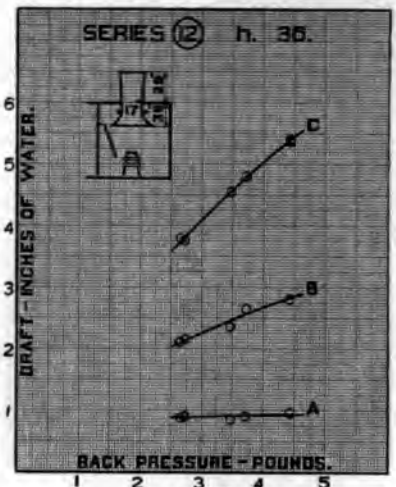


Fig. 97.

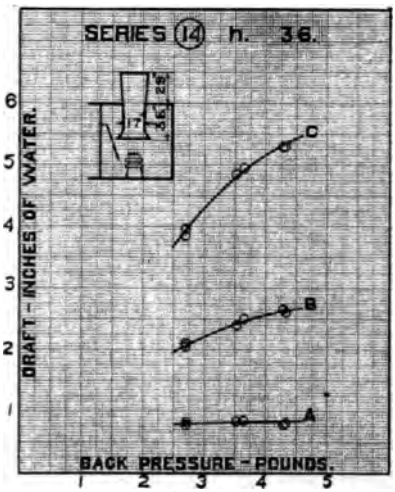
UofM


SERIES (12) h. 24.
DRAFT - INCHES OF WATER.
BACK PRESSURE - POUNDS.
A
B
C
Fig. 98.


SERIES (12) h. 36.
DRAFT - INCHES OF WATER.
BACK PRESSURE - POUNDS.
A
B
C
Fig. 99.

SERIES (13)

SERIES (14) h. 24.



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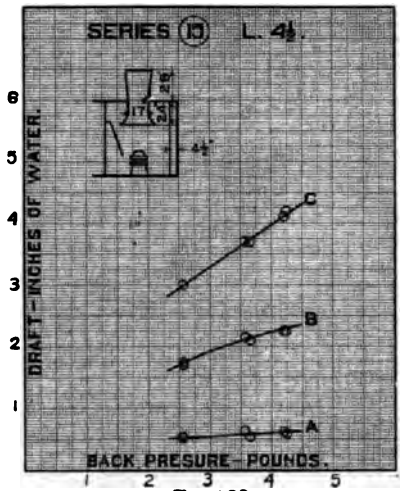

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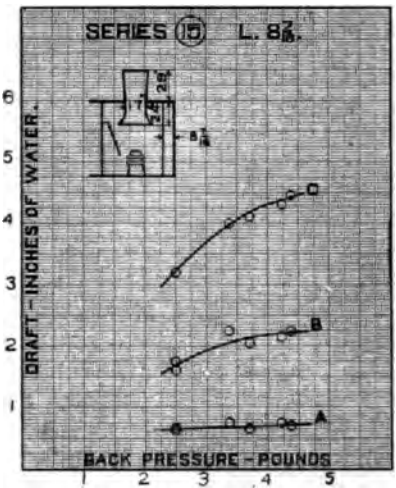


Fig. 104.

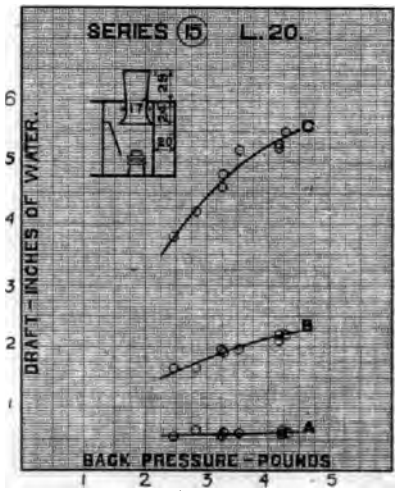
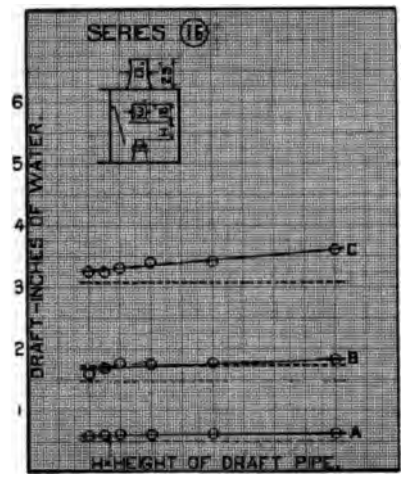


Fig. 105.

UOPN



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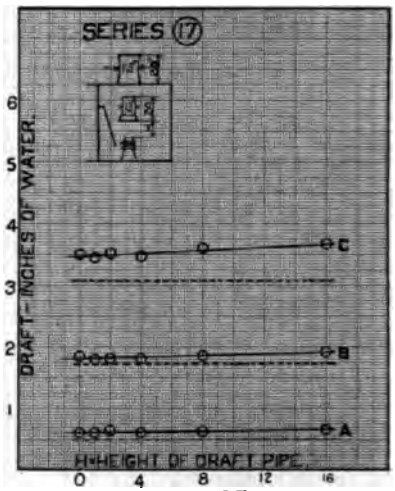

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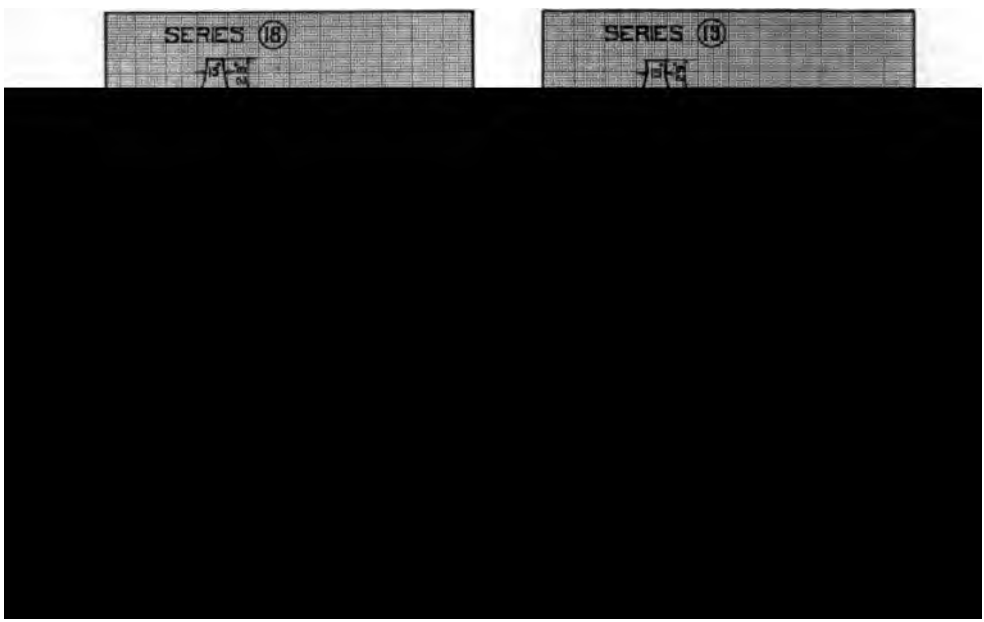


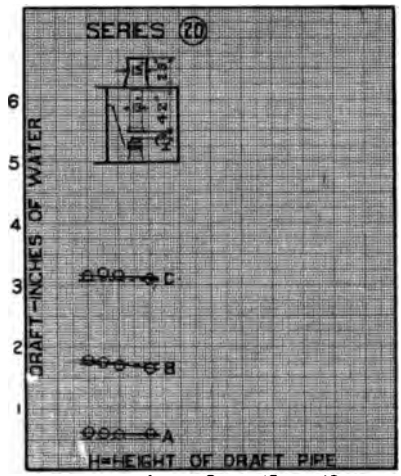


FIG. 110.

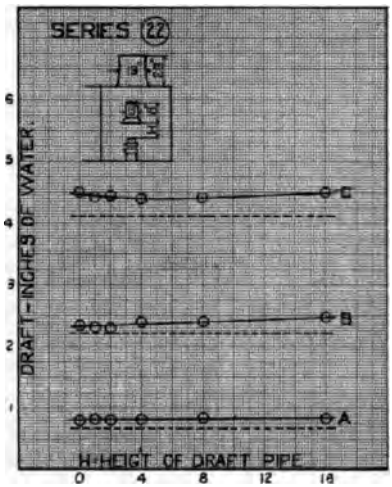
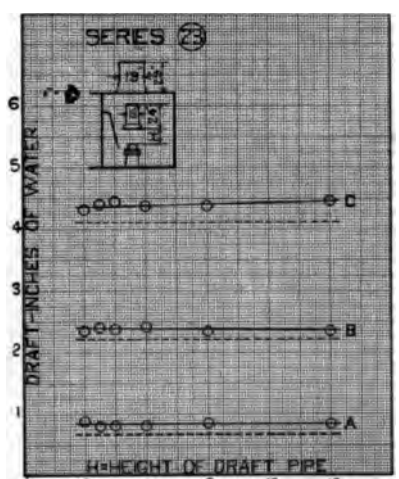


FIG 111



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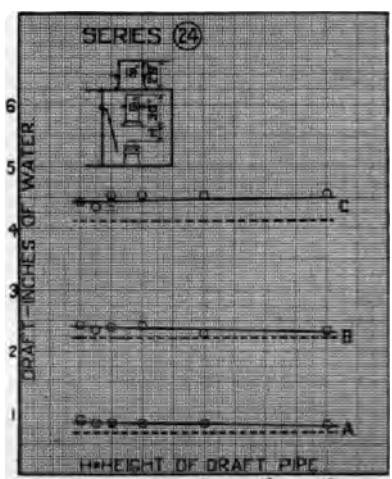


FIG. 113

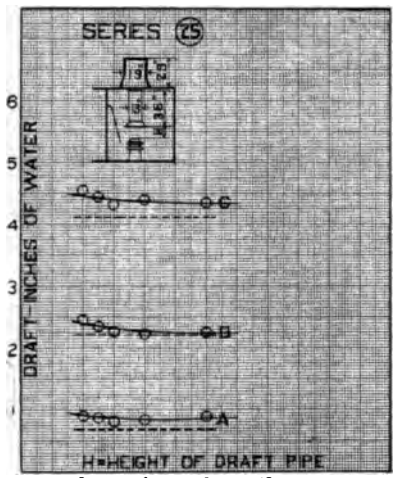


FIG 114

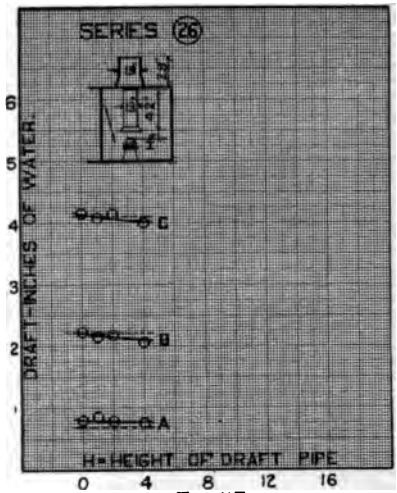


FIG 115

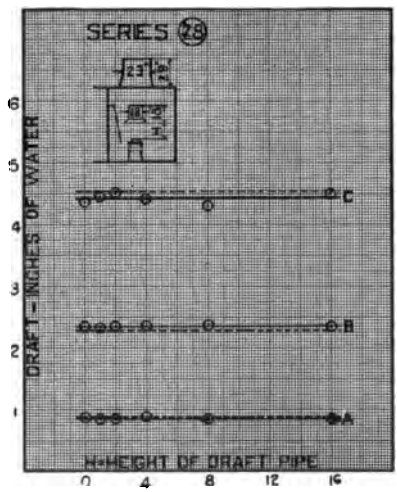


FIG 116

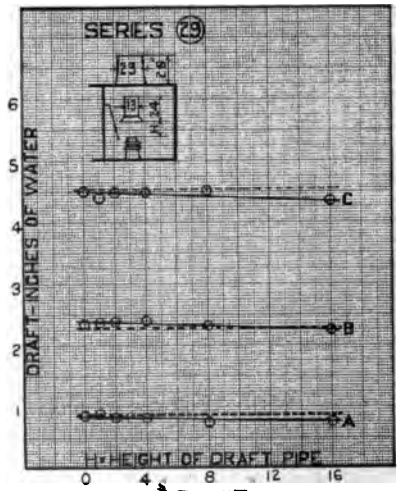
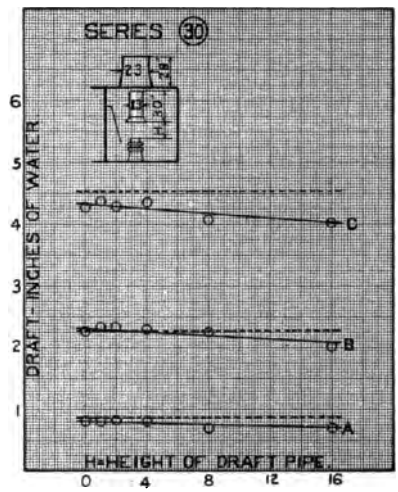


FIG 117.



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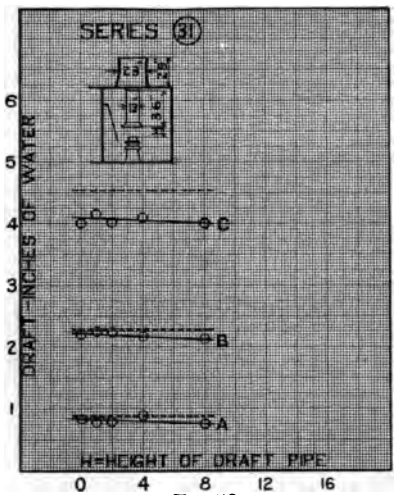

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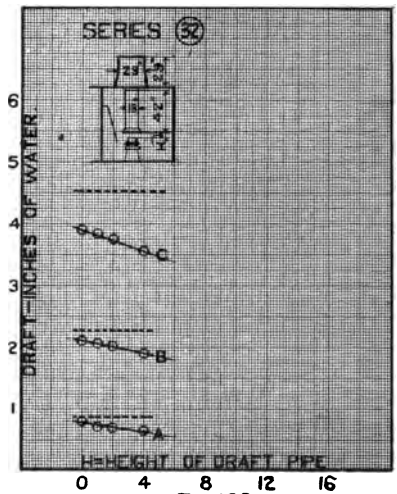
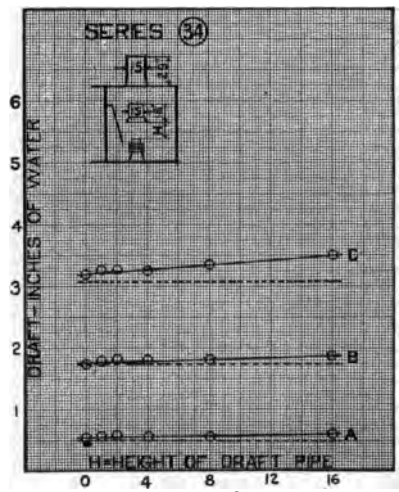


FIG 120.



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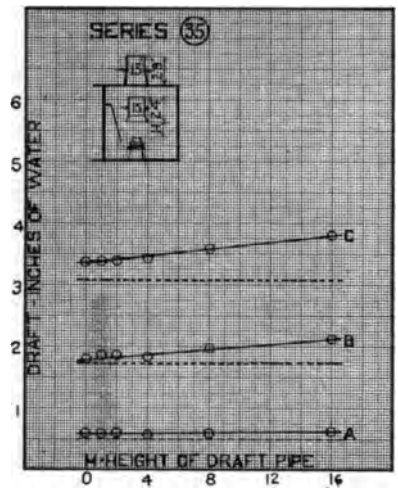

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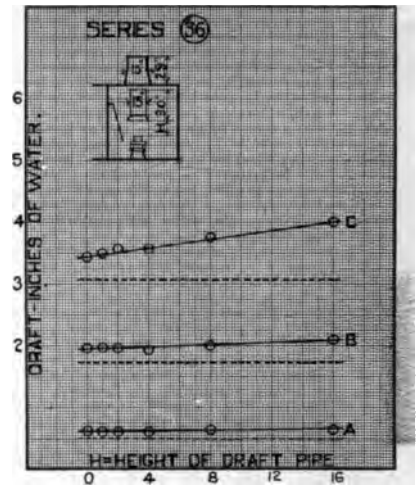
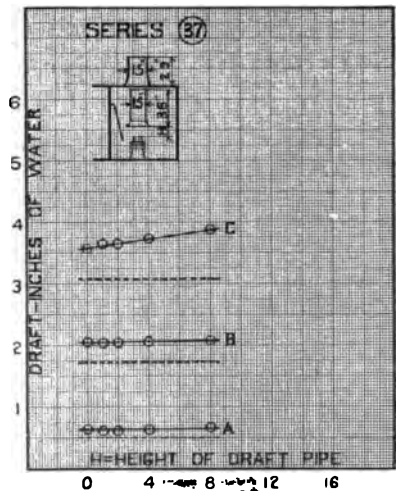


FIG. 123.



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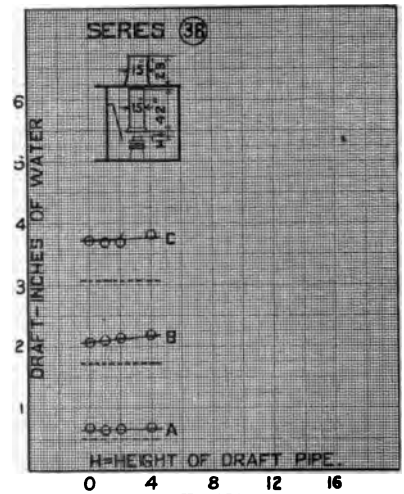

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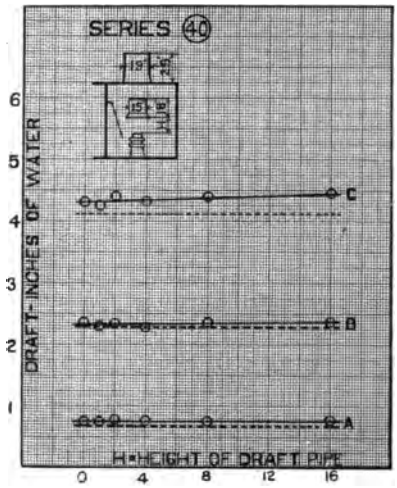

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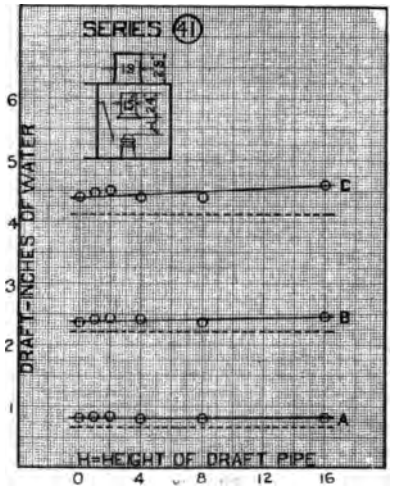

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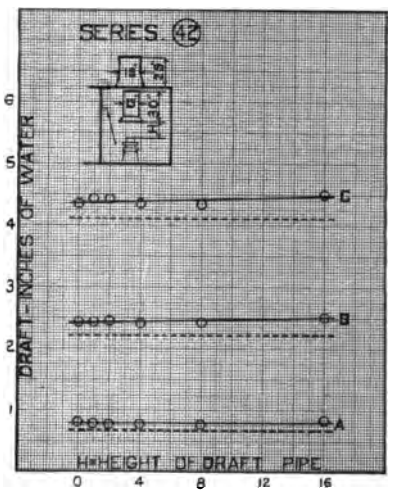

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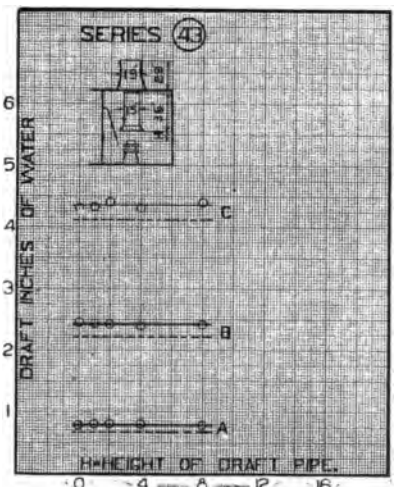

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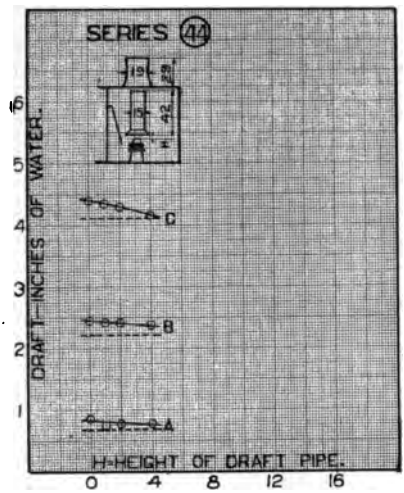

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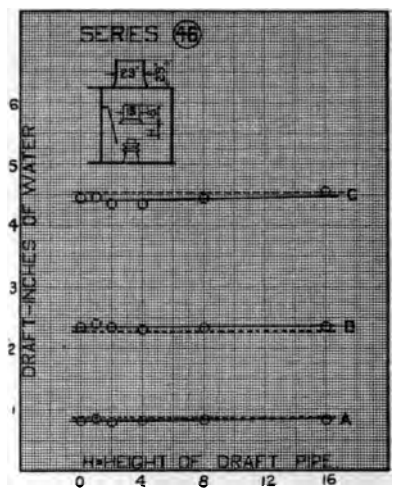

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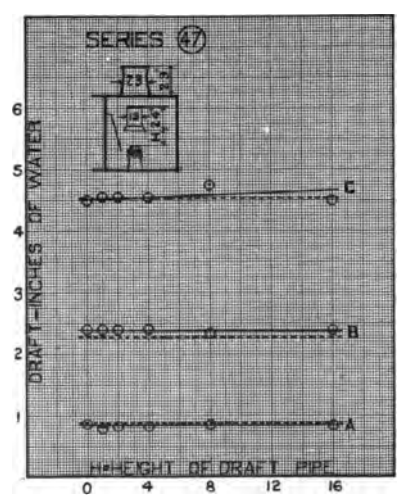
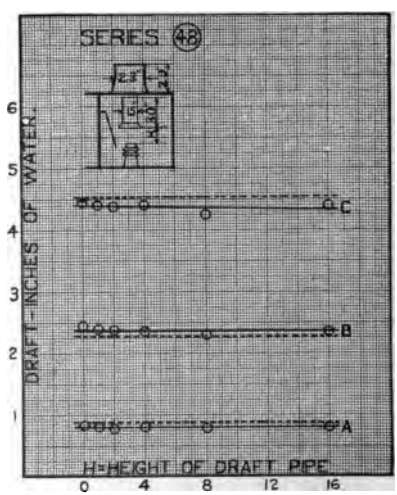


Fig. 132



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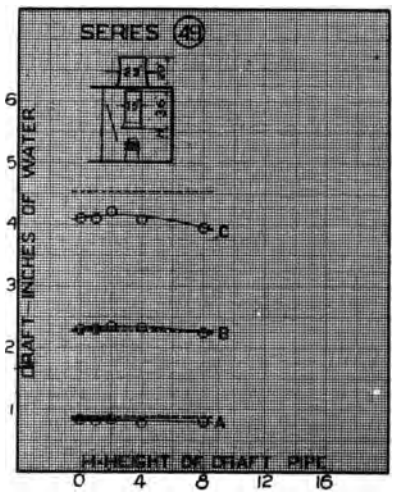

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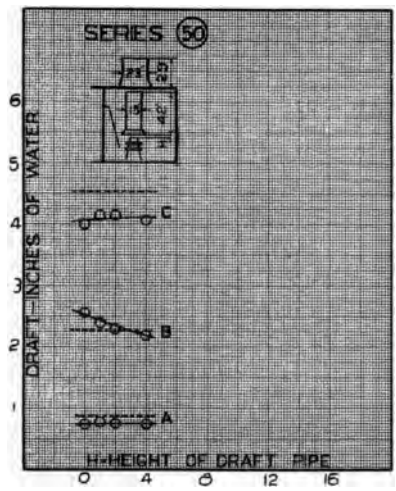

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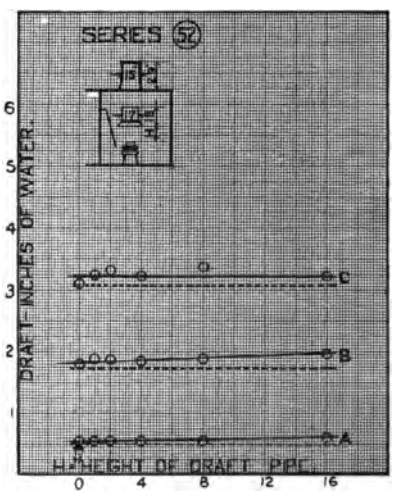

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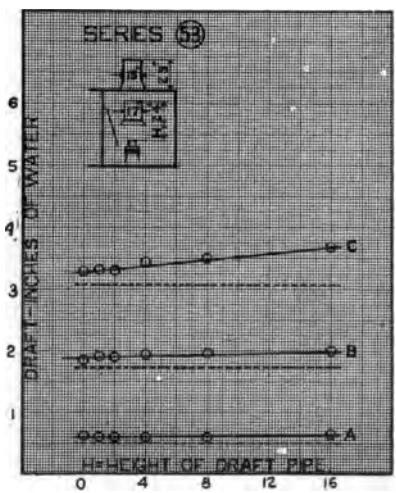

Fig. 137.

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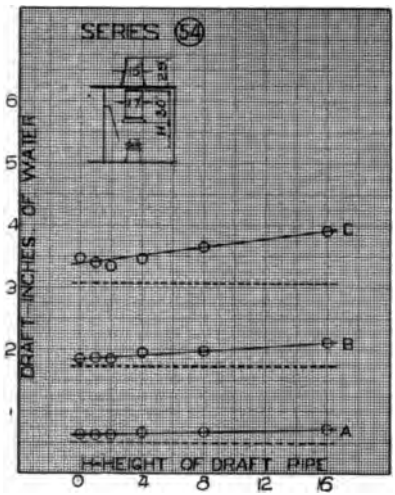
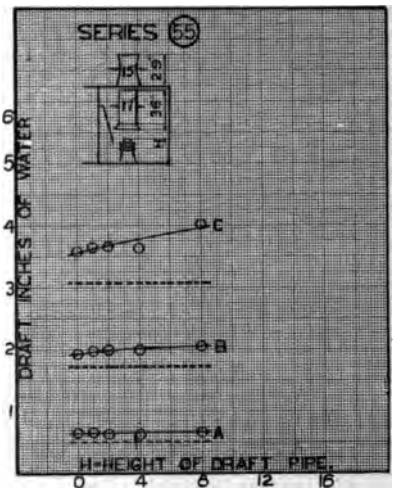


FIG 138



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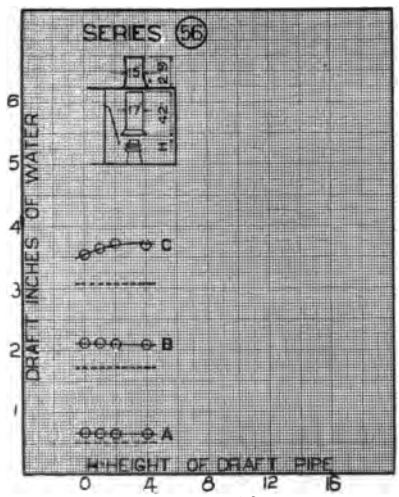

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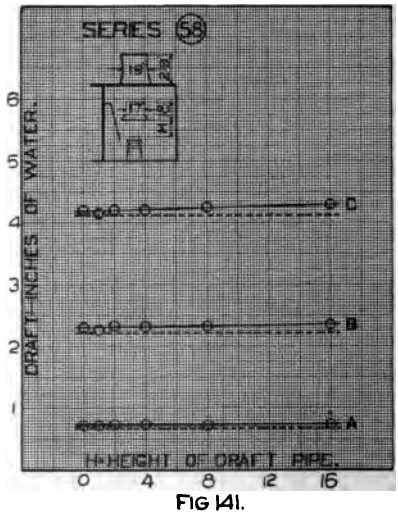

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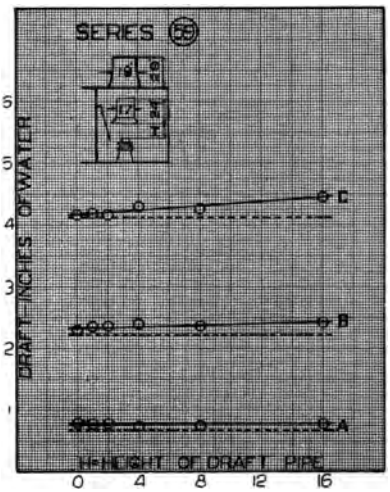
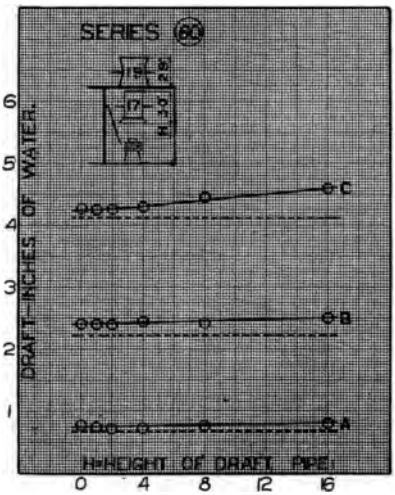


FIG 142



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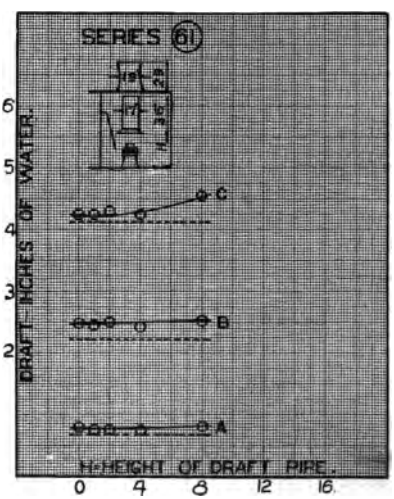

FIG.144.

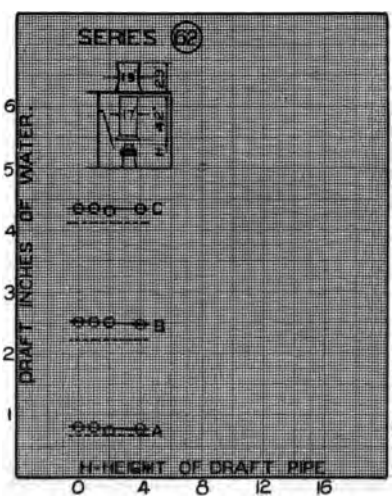

FIG. 145.

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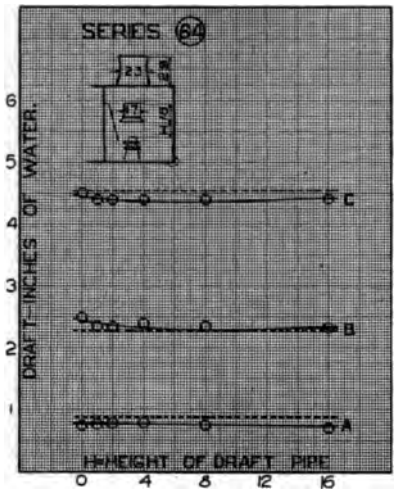

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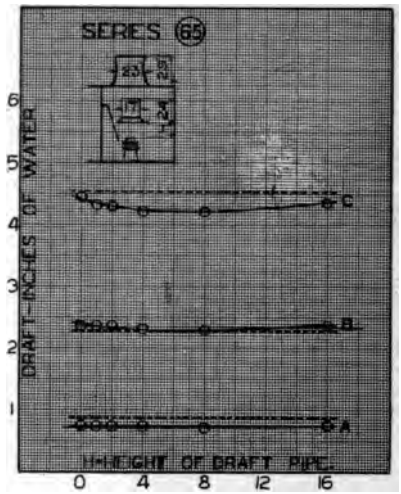

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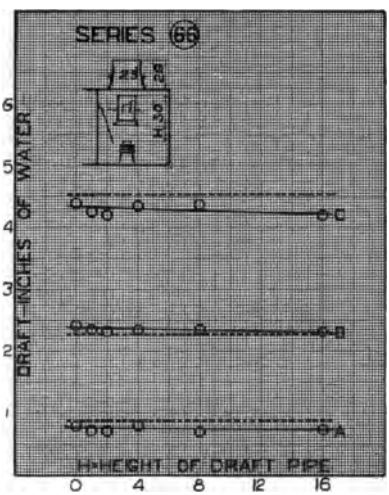

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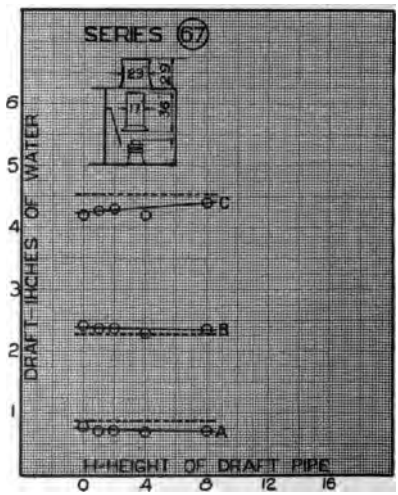

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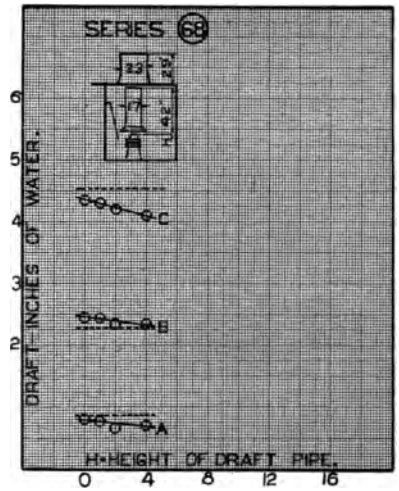

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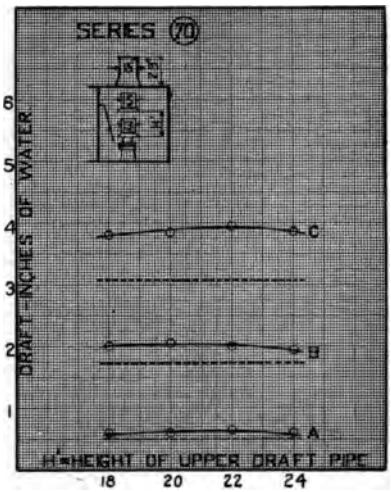

FIG. 151

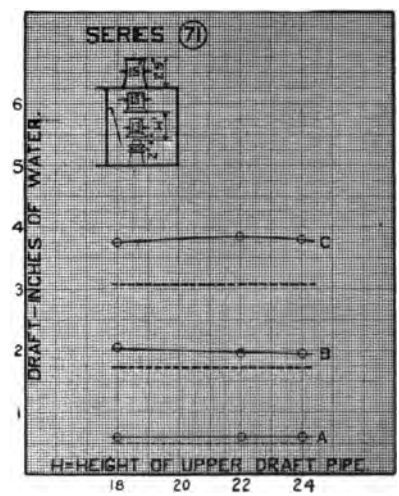

FIG. 152

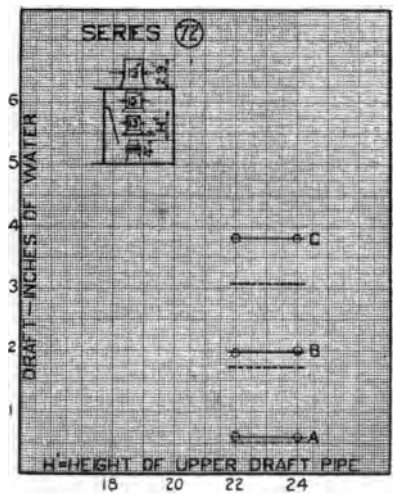

FIG 153.

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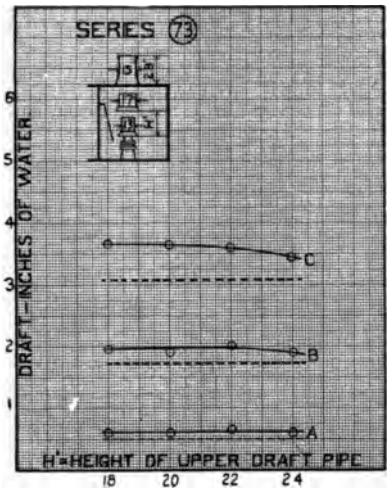


FIG. 154

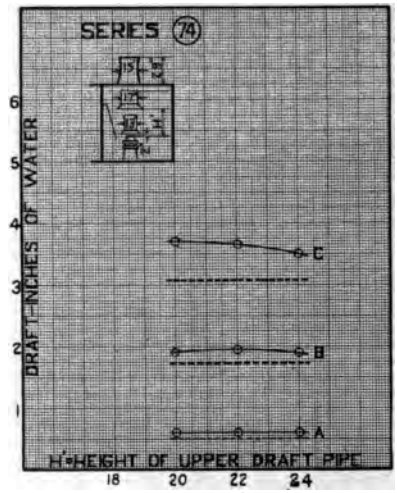
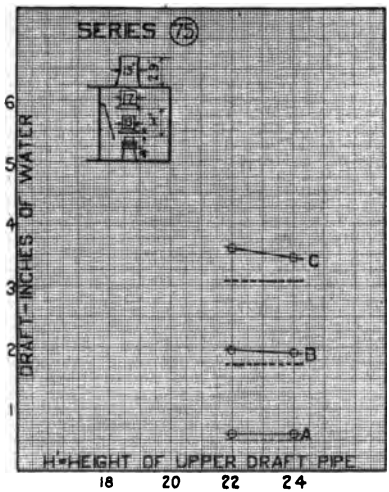


FIG 155



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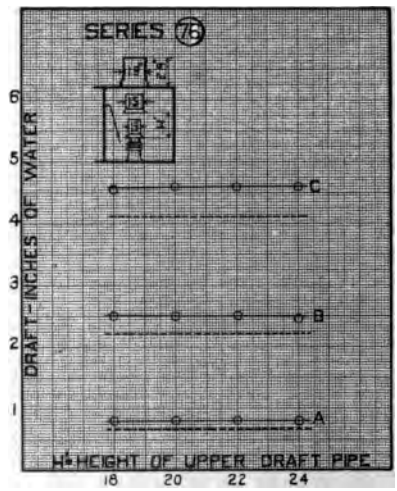


FIG. 157.

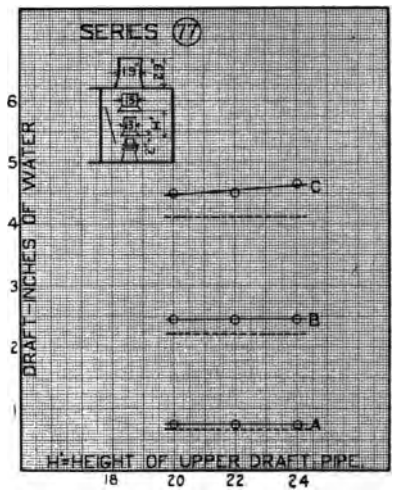
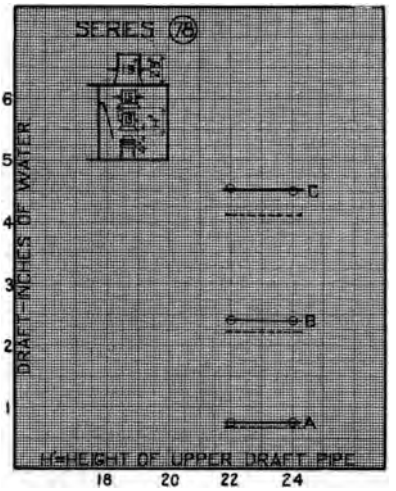


FIG. 158.



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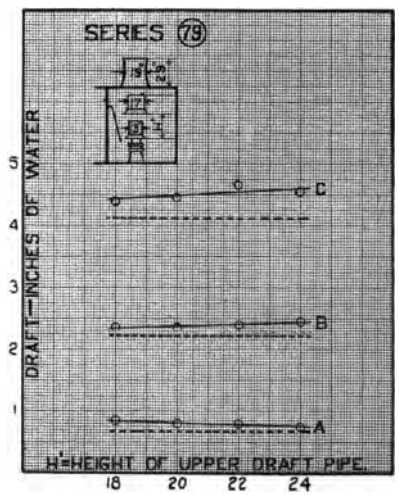

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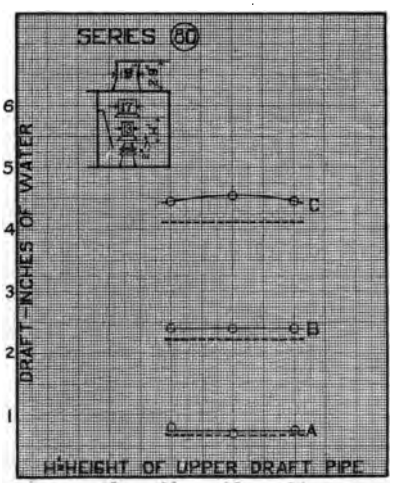

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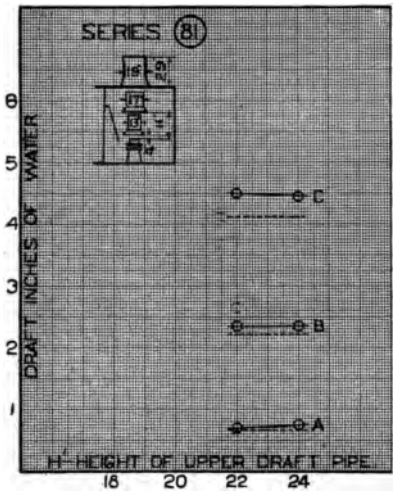

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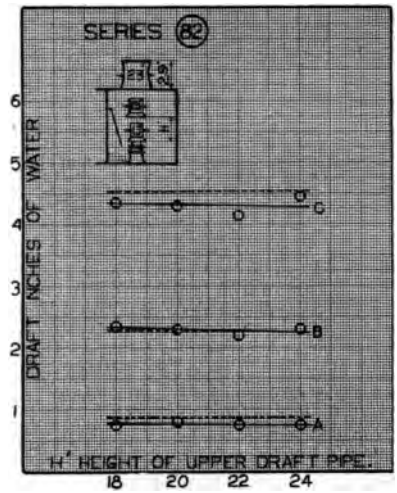

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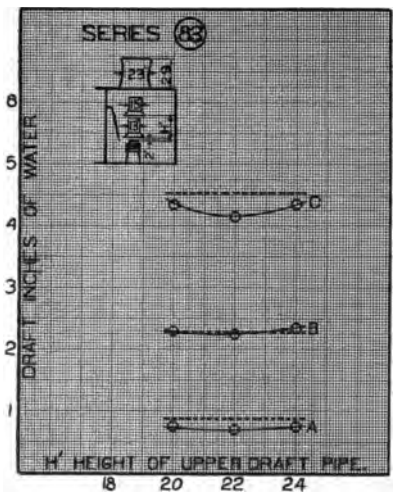

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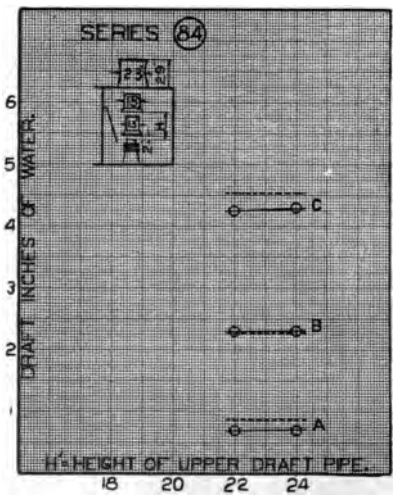
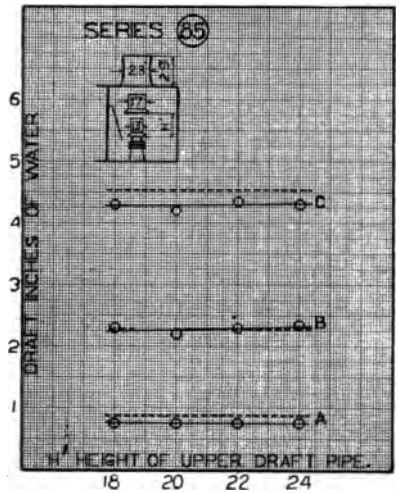


Fig 165.



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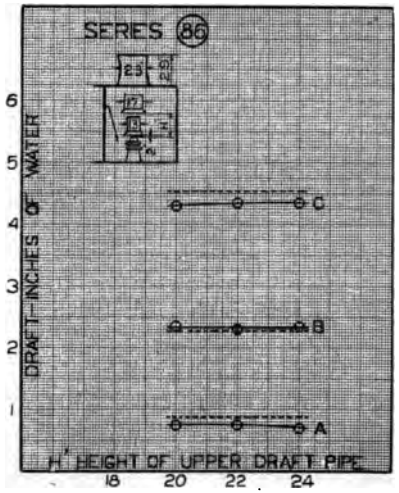

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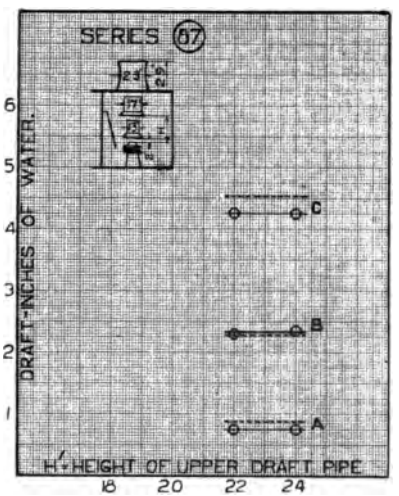

Fig. 168.

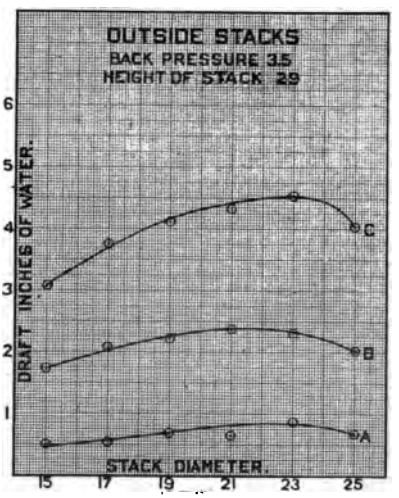

Fig. 169

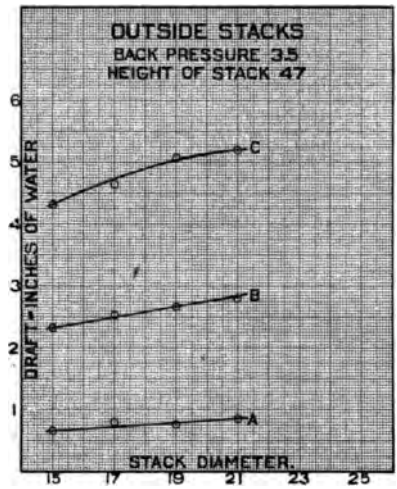

FIG. 170.

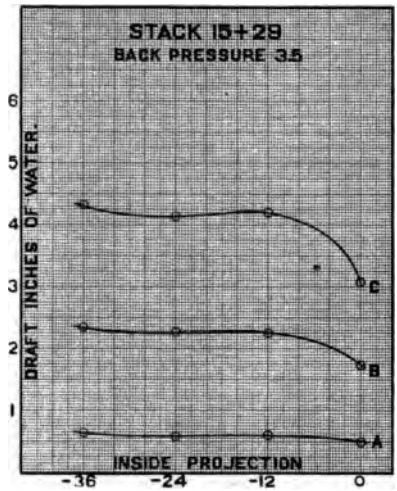

FIG. 171.

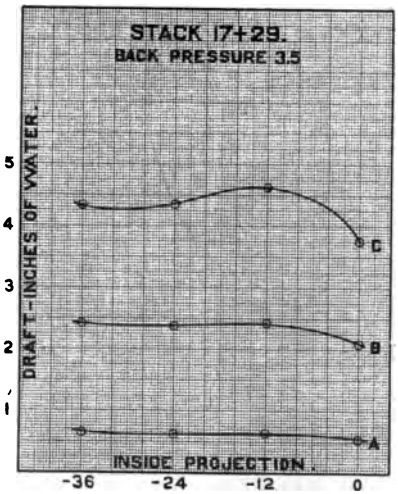

FIG 172

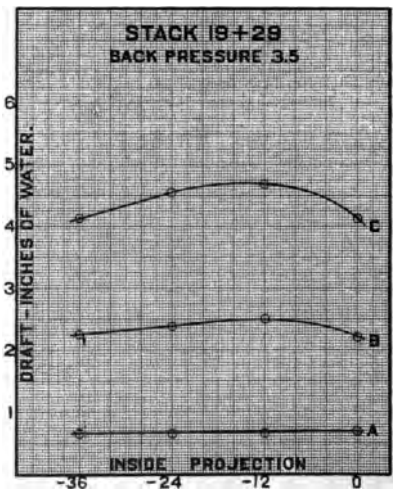

FIG 173

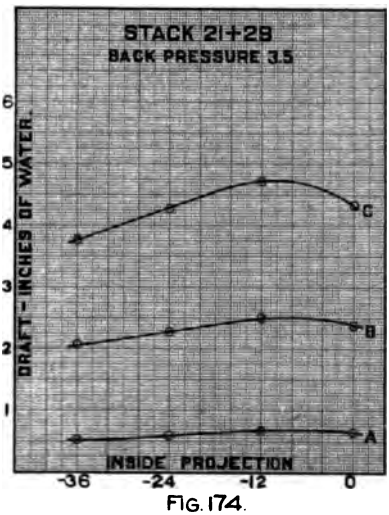

FIG. 174.

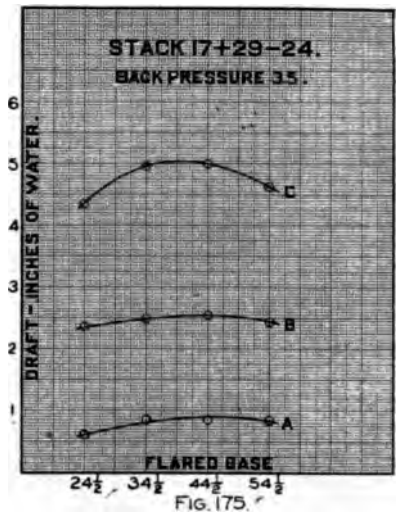

FIG. 175.

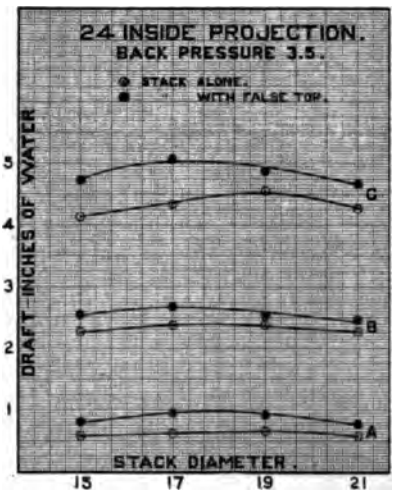

FIG. 176.

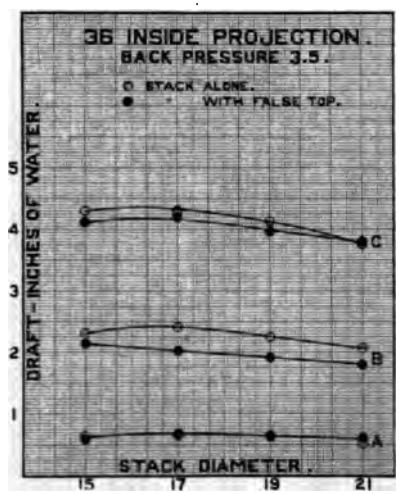

FIG. 177.

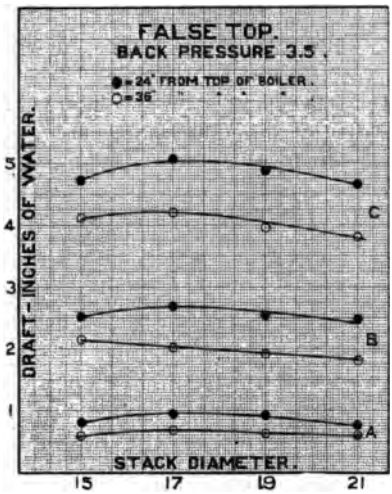

FIG. 178

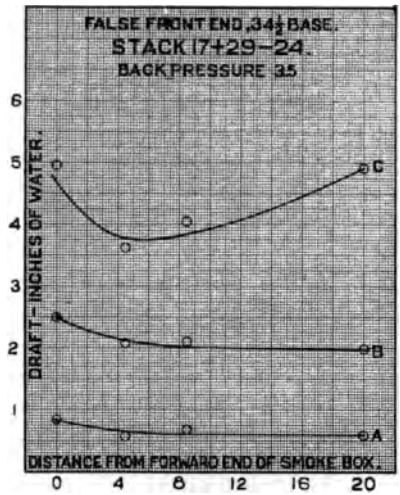

FIG. 179.

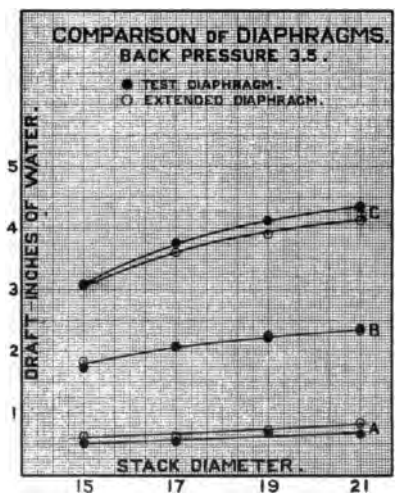

FIG. 180.

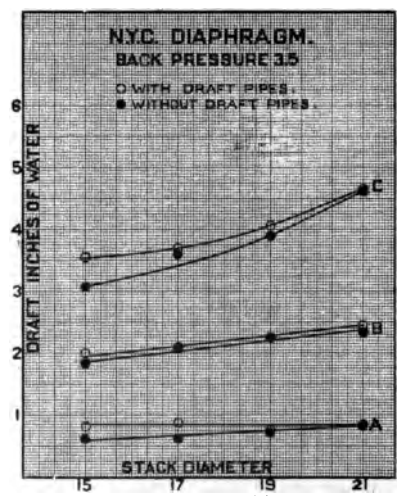

FIG. 181.

At the conclusion of paragraph 10, Mr. Vaughan, in presenting the report, said:

This is one of the points on which we can hardly regard the tests as entirely satisfactory. There is no doubt about the correctness of the results, but they are so exceedingly curious that we are practically at a loss to explain them. You will see that there is practically a twenty-five per cent loss in draft to a 4½-inch shortening of the front end from the normal figure, or from the figure that the New York Central engine has. This is a most peculiar result, and it is still more peculiar that as the front end is shortened still further the draft begins to improve again. It can only be explained, I think, by the fact that at certain lengths of the front ends the currents of gases move freely through the front end. We really do not know very much about the explanation. At least, I do not think so.

At the conclusion of the report proper, Mr. Vaughn stated that the minor investigation referred to would be reported on this morning. He continued:

I would like to make it clear that on page 4 has been shown the best combination of each of the different arrangements experimented with. For instance, Fig. 1 shows the best arrangement of plain stack, 29 inches outside; Fig. 2 shows the best arrangement with 47 inches outside; Fig. 3 shows the best arrangement with the stack penetrating the smoke box; Fig. 4 shows the best arrangement with the single draft pipe; Fig. 5 shows the best arrangement with the double draft pipe; Fig. 6 shows the best arrangement with the closed top to the smoke box; inside, false top; Fig. 7 shows the best arrangement with the flat plate at the bottom of the stack; Fig. 8 shows the best arrangement with the Belled stack; Fig. 9 shows practically Fig. 8, the best arrangement we have arrived at.

Then, turning over to pages 12, 13 and 14, you see for each of the variations in the different arrangements experimented with, the draft arrived at by modifications, and of course the best modification in any of those diagrams is the one shown on page 4.

In connection with Professor Teague's report, contained in the report of the committee, Mr. Vaughn said:

Before leaving Professor Teague's report I would like very

much to call your attention to some of the diagrams, say page 72 or 73 — any of those diagrams will do. Taking the diagrams shown on page 71, you will see that the various points determined, as shown by the circle on the diagram, fall with remarkable accuracy upon the lines or curves which are to represent the results. I do not know where we have ever seen a series of tests in which the results were plotted graphically so accurately. I think that we are to be very much congratulated upon the way in which Professor Teague has arranged the tests and the results he has obtained.

I would also say, on behalf of the Front End Committee, that our position has been almost as light a one as perhaps that of the directors of an insurance society. We have done very, very little in this matter. The entire work of the tests has been carried out by Professor Goss. The apparatus has been designed under his direction. The methods are his. The report is his. We can hardly say enough in our appreciation of the splendid way in which he has carried out the work, and our pleasure in being able to present such a valuable set of results as have been obtained by it to the Association.

THE PRESIDENT: If there is no objection, we will consider the report as being received and open for discussion.

MR. DAVID BROWN (D. L. & W.): Mr. President, this is a very valuable paper, and the committee is certainly entitled to the thanks of the Association for the manner in which they have attended to their duties, the care and attention they have given to it, and it will add to our records some very valuable information. I am interested in the subject because we follow the principles to a great extent on the road with which I am connected and these principles are in accordance with remarks that have been made at former discussions of this subject.

The committee states on page 3 that the best results were obtained from a 23-inch diameter stack with a height of 29 inches, which is about the limit of height that we can get with the modern engines having large boilers. Fig. 1, page 4, shows the results. Fig. 2 shows better results with higher stack, which is not practical. Fig. 3 shows it lowered into the smoke box, though not with as good results. Fig. 4 shows a draft pipe, but it is no

better than Fig. 1, without the draft pipe. Consequently the draft pipe would be considered an unnecessary expense. Fig. 5, with a double pipe, shows less results than Fig. 4 with a single one, indicating that we have been going to unnecessary expense. On page 7 the report says: "It was found that for the best results the presence of a draft pipe requires a smaller stack than would be used without it, but that no possible combination of single draft pipe and stack could be found which gave a better draft than could be obtained by the use of a properly proportioned stack without the draft pipe." All that goes to show that we have been going to unnecessary expense, not only in making the draft pipes but taking them in and out every time we do anything in the smoke box. The same remarks apply, on the same page, in reference to the double one. Page 11, the first series, from No. 1 to No. 6, shows that the small stacks are not to be considered. We get better results as we increase the diameter of the stacks, as shown on Nos. 7, 8 and 9. Also, at 7, 8 and 9 it shows that the shorter inside projection, No. 8, gives the best results. It shows that with the false top we have to use a smaller stack for the best results. Page 11, series 5, 6 and 7, we find that we do not gain much by going to the trouble of using the inside projection of the stack. Fig. 5, with the least projections, 12 inches, is better than 6 or 7, with 24 inches and 36 inches, respectively. Page 12, series 10, shows that the expense of a close-fitting false top is incurred. The results are no better than series 11 and 12 without that expense. Fig. 14 still further shows that a 24-inch projection for inside stack is better than a 36-inch projection. Series 15 shows conclusively that the smoke box should be as short as possible. Coming down to series 22, 23 and 24 on page 13, we note that on 22 we have a very indifferent looking draft pipe, that really looks as if we could get along just as well without it, and that shows nearly as good results as either 23 or 24 with long draft pipes. Page 14 shows the best results when bottom of draft pipe is down level with exhaust tips, and we go on to others 1 inch above, to another where it is 8 inches, others again 16 inches above, showing that there is a diversity in the heights from the tip of the nozzle to the bottom of the draft pipe. This goes to show that very little notice can be taken when our

engineers go east, have an engine failure through lack of steam, and in coming west have said they fixed it and made a good run, and we have asked "What did you do?" "Raised the petticoat pipe." "How much?" "Oh, an inch." Here we have the draft pipe from even with exhaust tip to 16 inches above, and all showing good results.

According to those figures referred to we find the committee is correct in its remarks on page 7, as to single and double draft pipes, that they are unnecessary when the stack is proportioned properly.

There is one other little matter that I consider unnecessary, too. If we have to get down to a stack 22 inches high, I do not see the necessity of enlarging it on the top, from the choke up. I think if we would run the stack straight up from the place that we call the choke it would give equally good results, it being too short to form the choke. When the choke was first brought out by the French engineers the stacks were long and small in diameter, and it was a benefit to increase it from the choke up, for the reason that there was less friction for the steam and gases passing through it. It had done its duty, and could be allowed to get out of the long stack freely. There was another matter at that time that they considered — the netting they had was a very crude affair on the top of the stack, with merely a ring and a center brace across it and some heavy wires running through, which was the only form of spark arrester in those days. By increasing the top of the stack 4 or 5 inches they were enabled to get a larger area of netting. But to-day everything is changed. The nettings are in the smoke boxes and smoke stacks are short. Consequently, I think if we give the necessary flare or bell mouth, whatever we like to call it, and reduce it to the choke, we then can go up straight, making the diameter large enough, in accordance with the committee's recommendation, to use a properly proportioned smoke stack.

MR. A. E. MITCHELL: Mr. President, I would like to ask the committee one question. As I understand it, this test was made without the netting. We all know that the netting produces a little reduction in the draft. Can we utilize these figures given here as correct as well with the netting as without?

MR. C. H. QUEREAU (N. Y. C.): Mr. President, I would like to call attention to just one thing; it will take me but a few minutes. It was stated the other day in the meeting that the full round of draft appliances had been covered. I would call attention to Fig. 53, page 47. By using the figure there given you will discover that, calling the draft in front of the diagram one hundred per cent, only fifty per cent of that draft is utilized back of the diaphragm. It seems to me this is a matter very well worth further investigation by this committee, and under the able superintendence of Professor Goss, to devise some form of diaphragm that will not waste fifty per cent of the draft created in front of the diaphragm. That can be done, I am satisfied.

MR. W. G. MENZEL (Wis. Cent.): Mr. President, I believe there is another point in this test that has not been fully brought out. We are liable to get the impression that it is a wrong idea to put in a petticoat pipe. Now, it is all right to know the best way to create power, but it is another thing to put it to its best use, and it is simply a matter of distributing the draft equally over all the flues, to get the best results. If a draft pipe brings about the result of distributing the draft, it is a good thing to use, even if it does not increase the amount of draft.

MR H. H. VAUGHAN (Can. Pac.): Mr. President, in closing this discussion, I refer first of all to what Mr. Brown said about short smoke boxes. These experiments do not show that the short smoke box is the best. If you turn to page 94, Fig. 179, you will see plotted the draft 1¼ inches, obtained with 3½ pounds of back pressure, where the false front was 0, 4, 8, 12, 16 and 20 inches back from the front end; that is, from the present position of the door. In other words, the results with the shorter boxes are to the right. Now, A is the draft in the fire box. That is the draft that counts. That gradually increases, if anything, as the front end is lengthened to its present length. B is the draft back of the diaphragm. That increases quite a little as the smoke box is lengthened to its present length. C is the draft above the diaphragm. That has practically the same value with a very short box and with the present length of box, but the probability is that some action takes place in the flow of air past the diaphragm that changes the value of that draft. As I would see it,

that draft is not a useful draft. There must be some peculiarity of action there changing that one figure, but that does not affect the draft on the fire. The draft on the fire with a given back pressure gets rather better as the front end is lengthened. I think that is correct.

With regard to taper stacks, it has been absolutely determined that a taper stack is better than a straight stack. That has been determined in each series of tests that has been carried out. Of course, what Mr. Brown says is all right in this way, that in all of this stack business a question of ½ inch or 1 inch one way or the other seems to make very little difference if you have a stack only 29 inches high, and you have a 15-inch height of choke. It does not really make much difference whether you make the stack straight or tapered, but where you get up to the long stacks, in which the taper is long enough to be of some service, then it is important to make it one in 6, two inches in a foot, total taper. There is no question about that. That has been absolutely determined.

With regard to what Mr. Mitchell stated about the netting, I would look at that in this way: We have found that the draft is a direct function of the back pressure. In other words, if you have a 4-inch draft, with a 3½-pound back pressure, you have an 8-inch draft with 7 pounds back pressure. If you put a netting in the way you simply put in an additional obstruction; you have to increase the back pressure to get a given effect on the fire. Providing that that law is true, and it has been, I think, proved time and time again, it simply follows that when you have the best arrangement for a given back pressure you also have the best arrangement for any other back pressure. If you put more obstructions in you simply have to decrease your nozzle.

As to what Mr. Quereau said about the diaphragm, this was referred to in the last report of the committee, in which we stated that while we recognized the need of an arrangement of front end that would do away with the excessive loss in dragging the gases past the diaphragm, yet we do not see and can not see how that can be carried out in the laboratory at present. The self-cleaning proposition has been developed to a point where it is almost universally used. It would be almost impracticable to

experiment on a various lot of self-cleaning front ends in the laboratory. To-day everybody is using a certain type of front end. If people will develop a type of front end which can obtain the results without the diaphragm in service, or several types of front ends, which can obtain the results without the diaphragm in service, it will then be possible to investigate that on a laboratory testing plant. I do not think it would be useful to go to work and develop a given type of front end on the laboratory testing plant. To begin with, you would have to use fuel oil on the testing plant to get results. That immediately stops ascertaining properly the distribution of draft on the fire. Two roads using different coals will want radically different adjustment to burn the fire properly. We have that on our road, certainly, on which the coal varies, Pittsburg coal in one place and Dominion coal in another, and we require different adjustments of diaphragms to burn the coal properly. The test at Purdue would not determine the matter, and it would be a matter of very great expense. I think that our position should be to determine arrangements and not to invent.

What Mr. Menzel says about the draft pipe is, I believe, certainly true. All we have done, however, has been to show the best arrangement for producing draft. If you find it impracticable to get the proper distribution of draft by diaphragm adjustments, you can see here the best arrangement of petticoat pipe. You can find out what the petticoat pipe means to you in loss of draft.

There is another point I would like to refer to — I meant to before. It struck me as very interesting. We have all had experiences where we have sent an engine out without a petticoat pipe. The local man has put in a petticoat pipe, and has reported it better. Even in the 1896 experiments, after they were all concluded, they then put back the arrangement that the engine had on the road, and it was better than any there. That was the arrangement. Now, we have finally explained that. For instance, if you turn to Figs. 1 and 2 on page 11 — suppose you had an engine with an 18-inch stack — that is, D-18. Fig. 2, you would have a 9½-inch draft. If you go to work and put in a double draft pipe, you have improved it practically ten per cent; that engine is reported as doing all right. Suppose you had a large

size stack, as shown in Fig. 2, 21-inch stack, and then you put in a petticoat pipe, and you get only one per cent of difference. In other words, there are lots of times when a petticoat pipe will improve the draft; but what we, I think, have shown, is that if you have the proper arrangement of stack and front end, you then can not improve it by putting in a petticoat pipe. You can improve improper arrangements; but I think that itself is really what we have done, because it is going to enable us, I think, to get away from draft pipes.

THE PRESIDENT: Mr. Whyte states that on the New York Central they have applied the proposed stack to some of their engines. Mr. Whyte, can you tell us about that?

MR. F. M. WHYTE (N. Y. C.): These locomotives have been very free steamers with the front end arrangements standard to them; therefore, the tests are hardly conclusive, except to show that the front end suggested by the committee is satisfactory for the locomotives and that there may be a possibility of increasing the diameter of the exhaust nozzle. The exhaust nozzle standard to the Atlantic type locomotive on the N. Y. C. & H. R. R. R. is 5¾ inches to 6 inches in diameter. The nozzles were made 6¼, 6⅜ and 6½ inches in diameter for use with the stack and front end arrangement suggested by the committees.

Results: On one division the locomotives having 6⅜-inch nozzles did not steam satisfactorily, trailed the smoke badly and did not clean front end, especially on horizontal plate of smoke box. Nozzles were changed to 6⅛ inches diameter. On another division the locomotives having 6⅜-inch nozzles gave practically the same results, except that locomotives made plenty of steam. On a third division the locomotives having nozzles 6 inches and 6¼ inches diameter performed satisfactorily in every way, except the trailing of black smoke and the accumulation of cinders on horizontal plate of smoke box.

The performance of the stack as a whole is considered good and the elimination of the lift pipe will be a decided improvement, if it may be omitted and still get rid of the cinders so as not to have them accumulate in the front end.

THE PRESIDENT: We would be pleased to have some remarks from Professor Goss in connection with this subject.

PROF. W. F. M. GOSS: I will take time only to acknowledge the more than courteous reference which Mr. Vaughan has seen fit to make to me and to the work of our laboratory, and to say in return that our part of the work has been rather a routine part. It has been the interest of this committee, sustained year after year over a considerable period — and especially the enthusiasm of its chairman — that has brought this investigation to a successful conclusion.

To that I shall be glad to add one more word. It is now fifteen years since the locomotive test plant at Purdue was first started, and of course it can not but be gratifying to me to see how steadily the operation of such a plant is growing in public appreciation and the increased confidence which the members of this Association are inclined to give to the results derived from such plants. In evidence of that we have at this session of the Master Mechanics' Association three papers, two of which have been presented and one yet to be presented, all of which are based upon the results of a locomotive testing plant. This progress in the adoption of a plant as a means of testing locomotives is a matter which, of course, gives me very great gratification.

MR. A. M. WAITT: It seems to me that the value of this paper is such that it would be fitting, and it is really called for, that this Association shall express its appreciation, not only of the committee which has so ably presented its report and has kept the necessary push behind the work to bring it to a most pleasant completion, but also to Professor Goss and Professor Teague, and their associates at Purdue University, and that they should be recognized formally. I move that we tender our hearty votes of thanks and appreciation to the committee, Professor Goss, Professor Teague and their associates of Purdue University, for their able work in connection with this valuable paper. (Seconded and carried.)

MR G. R. HENDERSON: I move that the subject be closed. (Carried.)

THE PRESIDENT: We will now take up the next report, that of the Standing Committee on Mechanical Stokers. In the absence of Mr. Garstang, Mr. J. F. Walsh will present the report.

Mr. Walsh presented the report as follows:

REPORT OF STANDING COMMITTEE ON MECHANICAL STOKERS.

To the Members of the Master Mechanics' Association:

GENTLEMEN,— Your committee appointed at the convention in 1905, to observe and report on the development of mechanical stokers for locomotives would report as follows:

Your committee has considered data obtained from several sources regarding automatic stokers for locomotives, but these data, in the opinion of the committee, are not sufficiently conclusive to submit to the Association, at the present time.

Since the last convention there has been little progress made in the development of the automatic stoker for locomotives, as in addition to continued trials of the stoker mentioned in the Proceedings of the 1905 convention, the committee has advice of trials of but one other stoker. This stoker had in connection with it, apparatus for conveying the coal from the tender to the stoker hopper above the fire door. The types of locomotives, nature of service and kinds of coal used by the various railroads, make it very difficult, at the present time, to make any valuable comparisons of the performance of the various types of stokers.

W. GARSTANG, Chairman,
D. F. CRAWFORD,
J. F. WALSH,
Committee.

INDIANAPOLIS, IND., May 24, 1906.

THE PRESIDENT: Gentlemen, you have heard the report. What action will you take upon it?

MR. A. M. WAITT: I move that the report be received and the committee continued. (Motion carried.)

THE PRESIDENT: The next business is the report of the Committee on Classification of Locomotive Repairs. Inasmuch as this is not a lengthy report and it is a very good one, I think we had better have it read through.

Mr. H. H. Vaughan, chairman of the committee, presented the report as follows:

REPORT OF COMMITTEE ON CLASSIFICATION OF LOCOMOTIVE REPAIRS.

To the Members of the American Railway Master Mechanics' Association:

Your committee appointed to recommend a uniform system of classification of locomotive repairs considers this subject to properly comprise the following three separate questions:

1. A classification distinguishing between those engines which are in service and those which are under repair.

2. A classification distinguishing between those engines which are under running repairs and those which are under shop repairs.

3. A classification distinguishing between the various classes of shop repairs.

The distinction between engines in service and those under repair was, some years ago, very generally made by considering all engines in service which were not under or waiting repairs at a main shop or undergoing light overhauling at a roundhouse, and this practice which is, in many ways, satisfactory, is still in force on many roads. With the increasing demands on an operating officer for obtaining the maximum service from the power assigned to him, it has become customary to establish some limit to discriminate between those engines from which he should be expected to obtain service, and those which, although not actually shopped, are held at the roundhouse for a sufficiently long time to make it unreasonable to include them in calculating the average daily mileage. As it is recognized that engines must receive small repairs from time to time, it is evidently simply a matter of agreement as to where the prescribed line should be drawn, but in view of the comparisons that are frequently made between one road and another as to the percentage of their power that is available for service, a uniform definition of this limit is important if such comparisons are to be of any value.

The distinction between running and shop repairs is at present largely a question of individual preference. Several roads have, however, already arranged their locomotive performance sheets to show the costs of these two divisions separately, and as this is of considerable importance in statements attempting any accurate comparison, it would be of indubitable advantage if uniformity could be secured.

The distinction between the various classes of shop repairs is made for two purposes; first to indicate in a general way, the nature and extent of the repairs made to an engine, and secondly to allow of a rough measure being obtained of the output of a repair shop. In neither of these cases is a close definition possible without more complication than is either practicable or desirable. The detail repairs vary to such an extent on engines between which differences can not be specified in any classification having a reasonable number of headings that, for the purpose of accurate compari-

son, either of one shop with itself, or of the various shops on a system, the costs or times required for specific operations must be dealt with, and not those of the accumulation of a number of those operations which may not correspond within wide limits even on engines which, as closely as possible, would be said to receive the same class of repairs. There would thus be but little advantage in the use of a uniform classification of shop repairs, and the object of this report is consequently to discuss the various systems employed and point out their respective advantages.

To obtain information as to the practice existing in the above respects, the following letter of inquiry was issued:

"1. How do you distinguish between engines in service and those undergoing or waiting repairs, whether in roundhouse or shop?

"2. If you have a limit, how is it defined?

"3. If defined by considering an engine out of service if held for repairs for a certain time, such as twenty-four or forty-eight hours, does that time commence when an engine is called for and not ready or does it commence when an engine arrives at the roundhouse?

"4. Do you make any distinction between running and shop repairs?

"5. If so, how is the distinction defined?

"6. Have you any classification of shop repairs?

"7. Please send, with your reply, five copies of your classification of shop repairs.

"8. Do you advocate any system of classification distinguishing between engines in service and those under repairs, between running and shop repairs and any system of classifying shop repairs other than that you are now using. If so, describe the system you would recommend and give reasons for its use."

Replies were received from a comparatively small number of roads, but as those answering include most of the larger systems, the information obtained is fairly representative and is tabulated below to show the regulations in use defining engines in service and those under repair, and running from shop repairs.

Name of Road.	Limit distinguishing between engines in service and those under repairs.	Limit distinguishing between running and shop repairs. Tires not turned.
Atchison, Topeka & Santa Fe	Twenty-four hours from arrival.	$50.00.
Atlantic Coast Line	When wanted for run	
Baltimore & Ohio	If held for any repairs	$25.00.
Buffalo, Rochester & Pittsburg	Twenty-four hours from arrival.	Work done in r'dh'e.
Canadian Pacific	Twenty-four hours from arrival.	$100.00 labor.
Canadian Northern	Twenty-four hours from arrival.	Not out of service.
Central Railroad of New Jersey.		
Chesapeake & Ohio	Twelve hours from arrival	$300.00.
Chicago & Alton	Twenty-four hrs. from time arr'd	$50.00.
Chicago & North-Western	Not ready when wanted	Roundhouse work?
Chicago, Burlington & Quincy	Shop repairs	$250.00.

Name of Road.	Limit distinguishing between engines in service and those under repairs.	Limit distinguishing between running and shop repairs. Tires not turned.
Chicago, Milwaukee & St. Paul.	Twenty-four hrs. from time arr'd	Tires, flues or $200.
Delaware & Hudson	Twenty-four hours from arrival.	$100.00.
Denver & Rio Grande	Twenty-four hours from arrival.	
Duluth, South Shore & Atlantic.	Twenty-four hours from arrival.	None.
Grand Rapids & Indiana	Shop repairs	Tires or $10.00.
Illinois Central	Five days	$100.00.
Lake Shore & Michigan South'n.	Four days from arrival	R'dh'e class of work.
Mexican Central	Twenty-four hours after arrival.	None.
Minneapolis & St. Louis	Not ready when wanted	Roundhouse work.
Northern Pacific	Twenty-four hours from arrival.	$400.00.
New York, Ontario & Western.	Twenty-four hours from arrival.	By money value.
Pennsylvania Lines West	Twenty-four hours from arrival.	$10.00.
Seaboard Air Line	Twenty-four hours from 7 A.M.	Not out of service.
Southern Pacific	Held for repairs over $75	$75.00.
Union Pacific	Held for repairs over $75	$75.00.

I.

A classification distinguishing between those engines which are in service and those which are under repairs.

An examination of this table shows a very general agreement that engines not ready for service within twenty-four hours of the time they arrived at the roundhouse should be considered out of service or under repairs. There is evidently a wide variation in this respect, one road considering an engine under repairs if not ready when called, while others do not consider an engine out of service unless it is shopped. The latter system would be objected to on many roads for the reasons mentioned in the introductory paragraphs, while the former if rigorously followed would certainly lead to large numbers of engines being cut out for short periods at busy seasons when power is called for as quickly as it can be turned, and while, perhaps, logically correct, would seem to defeat its object by rendering it difficult to draw the line between good and bad service. Supposing, for instance, an engine to have been coaled, watered and its fire to have been cleaned in two hours, there would appear to be but little advantage in reporting it as out of service if held for repairs for one or two hours in addition. The majority of roads keep records showing the time in which each engine is turned and compile reports showing the daily performance at each roundhouse, so that a time limit above which an engine is considered out of service is also a time limit below which an engine is included on the time turned report. This division also separates those engines which will be turned without special delay from those which are held for a considerable time and which it may be possible to return more quickly to service by personal attention on the part of the Master Mechanic. Hence on the one hand it is not advisable to set the time limit too high, as the turning report becomes unduly complicated and the superintendent is charged with power which he is unable to use, while, on the contrary, if set too low, engines

which would be shortly dispatched are included with those seriously delayed and attention is not then specially directed to them. It is thus practically necessary to establish a reasonable limit, and as your committee considers that of twenty-four hours meets the requirements outlined above most closely, and it also agrees with very general existing practice, they would recommend its adoption. Such a limit should, however, not apply to assigned engines which are ready in turn for their run, or to helper or switching engines in twenty-four hours' service which must evidently be considered as assigned engines not ready for their run, if held for repairs when required, and your committee would therefore recommend as follows:

Engines should be considered as under repairs if not ready for service within twenty-four hours of their time of arrival at the roundhouse, or in the case of engines assigned to regular runs or in helper or switching service, if not ready for their run.

II.

A classification distinguishing between those engines which are under running repairs and those which are under shop repair.

The table shows very little agreement with reference to the distinction between running and shop repairs, and illustrates, what has previously been mentioned, that this is very largely a question of individual preference. In its broadest sense the division should be made by terming those repairs which are incidental to the maintenance of an engine in service and the amount of which is approximately proportional to the miles run by the engine, running repairs, and those in which a number of the parts of an engine are repaired or renewed and place it in condition for making a further number of miles, shop repairs. The amount of the shop repairs is evidently independent of the miles run in the month during which they occur, and its nature is that of an occasional as against a continual maintenance charge. A further condition must also be observed, that repairs of sufficient magnitude to be individually worth analysis should be considered shop repairs, as running repairs are very generally reported as a total monthly sum and no record kept of the cost of each shopping. On some roads this represents simply the difference between work done in the shop and in the roundhouse, while on others, where main shops are conveniently situated, it is quite usual to do repairs in them that are essentially running repairs, while in many cases, also, work of considerable magnitude is handled in the roundhouse; and to obtain uniformity some more definite limit than this must be established.

While this can not be done with any logical accuracy it is evidently in accordance with general practice to define it by the amount of money expended, and, if accounts are to show the cost of running and shop repairs separately it is preferable that this represent the estimated rather than the actual cost.

In that case when an engine is reported under repairs, it is at the same

time reported as under shop or running repairs, as the judgment of the foreman may determine, and the cost of the work booked accordingly. On this acccount there is also an advantage in basing the limit on the value of the labor expended, in place of on the total of material and labor, as it can in general be more closely estimated, and in repairs of this nature the cost of the labor is also a better indication of the extent of the repairs effected than is the total cost of material and labor. On this basis your committee considers it may be stated that repairs on which the labor is under $50 might safely be described as running repairs, while those on which it is over $100 would certainly be of sufficient importance to warrant them being individually reported and considered as shop repairs; and in view of the constantly increasing size of locomotives and the desirability of avoiding unnecessary complication it would select the higher limit as preferable.

Running repairs are those, whether made in shop or roundhouse, in which the estimated labor does not exceed $100.

III.

A classification distinguishing between the various classes of shop repairs.

The system in use for classifying shop repairs varies with each road or group of roads reporting. What may be termed the money system is in extended use, in which the class of repairs is graduated by their cost, varying frequently with the size of the engine. It is difficult to see what object is served by a classification of this nature, as it affords no information as to the work done on the engine and the shop output can only be measured by the total sum expended. If, for instance, on any class of engine a No. 2 repair is defined as one costing between $1,500 and $1,000, while a No. 3 costs between $1,000 and $500, and one shop is doing the same class of work for $900 that another does for $1,100, the first shop would only receive credit for a No. 3 repair while the other would be credited with a No. 2, so that evidently this method is of no use as a measure of output. It may be objected that no classification can be of any use, but this would appear to be about the only argument justifying a classification by cost.

The simplest and what may be termed the most primitive method is that where repairs are classified as light, general and heavy, but it is evident that such a classification does not afford specific information with regard to the work done, whether tires were turned, tubes reset, and the extent to which the machinery and boiler was repaired. It has therefore been developed by increasing the number of classes up to six or eight, each class defining such combinations of repairs as are found to usually accompany each other. A good example of this system, which may be termed the numerical and which is representative of that used by many roads, is herewith presented :

Class 1 repairs contemplate a new boiler, and all necessary work in addition thereto.

Class 2 repairs cover new fire box, tires turned or renewed if necessary, and all necessary machinery repairs.

Class 3 repairs; all flues reset or renewed, tires turned or renewed, and necessary machinery repairs.

Class 4 repairs; flues reset or renewed, either full or part set, and necessary repairs to machinery.

Class 4a repairs; one-third or less flues reset or renewed, tires turned or renewed, and necessary machinery repairs.

Class 5 repairs; ties turned or renewed, and such machinery repairs as are necessary.

Class 5a repairs; any repairs which are not included in the above classes, except accident repairs. Class 5a repair is generally machinery repairs of which the labor cost amounts to more than $10.

Class 6 repairs; repairs which are due to accident and for which the Motive Power is not responsible.

This type of classification has the objection that in spite of the number of classes of repairs, the information obtained is quite indefinite. The classes of repairs Nos. 1, 2, 3, 4 and 5, inclusive, vary simply according to the amount of boiler work performed, and the information obtained is that tires have been turned and machinery repaired with the following boiler work:

Class 1, new boiler.
" 2, all tubes reset.
" 3, new fire box.
" 4, one-third or less tubes reset.
" 5, no tubes reset.

No distinction is thus made between an engine having side sheets and front tube sheet removed and one in which no fire-box work is done, and it would certainly appear that such differences should be recognized in any classification for the purpose of obtaining definite information. A further objection is that Classes 4 and 5 are the only ones in which any distinction is made as to the extent of the machinery repairs, as in those classes tubes are not turned or renewed; but otherwise no information is obtained as to whether machinery repairs are light or heavy, and in view of the common practice of giving engines intermediate repairs to machinery, it would certainly be an advantage to indicate what was done. It would, however, on this system introduce at least three additional classes, as Classes 3, 4 and 5 repairs might each include light or heavy machinery repairs. If this were done there would then be ten classes of repairs, without including those required if the fire-box work were more closely specified, and the tabulation of those to present any intelligent comparison of shop output would certainly be exceedingly difficult. While, no doubt, the system has worked

exceedingly well, especially on roads where the conditions were more or less uniform and the repairs were very generally capable of classification under two or three numbers, it has evidently the fault of specifying by a number each combination of repairs to boilers and machinery, and necessarily becomes complicated if the combinations vary from time to time.

An analysis of this system shows that the various elements entering into the above classification are as follows:

1. New boiler.
2. New fire box.
3. All flues reset.
4. One-third or less flues reset.
5. No tubes reset.
6. Machinery repairs with tires turned.
7. Machinery repairs without tires turned.

These various elements have been combined in seven different ways covering those most likely to occur in service, but from the above discussion other elements might with advantage be introduced as follows:

8. One fire-box sheet renewed.
9. Two fire-box sheets renewed.
10. Three fire-box sheets renewed.
11. Four fire-box sheets renewed.
12. Tires turned with general repairs to machinery.
13. Tires turned with light repairs to machinery.

When this is done the number of combinations that may occur becomes far more numerous, as either 8, 9, 10 or 11 may occur with 3, and with either 12 or 13 into which 6 has been divided, and as information as to these elements is certainly required to define the repairs received by an engine, the numerical system practically becomes unwieldy, and it has on several roads been developed into the divisional system in which a combination of letters or numbers is used to indicate the repairs received.

An inspection of the various elements enumerated above shows that they may be divided into three divisions — machinery, tubes and fire box, as follows:

Machinery repairs:

1. General repairs to machinery with tire turning.
2. Light repairs to machinery with tire turning.
3. Light repairs to machinery without tire turning.

Flue repairs:

1. All reset.
2. Part reset.

Fire-box repairs:

1. One sheet.
2. Two sheets.

3. Three sheets.
4. Four sheets.
5. Five sheets.

On the divisional system, in place of specifying certain combinations of these elements and assigning a number to each combination, the class of machinery tubes and fire-box repairs effected are mentioned separately, as, for instance, an engine having a general repair to machinery, all tubes reset and two fire-box sheets renewed is said to have a No. 1 machinery, No. 1 tube and No. 2 fire-box repair. This may be abbreviated to M. 1, T. 1, F. 2 or more simply to 1-1-2 providing zero is understood to mean no repairs and the class of repairs received by an engine within the limits of definition included in the list of elements is thus concisely and clearly determined. It is evident that this system does not attempt any closer definition of the class of repairs received than does the numerical, but it states them in a more convenient way and also enables reports to be more closely arranged.

The heading required for reporting engines receiving repairs at any station is as follows:

Engine Number.	Class of Repairs.			Other Information as Required.
	M.	T.	F.	
1,000	1	1	2	

The statement of engines turned out at various points during any period is as follows:

Shop.	Machinery.			Tubes.		No. of Fire-box Sheets.	Other information as to days or under repairs, running repairs, etc.
	1	2	3	1	2		
New York	17	12	8	22	10	12	

It will be noticed that the report of engines receiving repairs defines the work done to each engine, while the statement showing the repairs made at each shop does not connect the repairs made to each engine but simply summarizes the amount of work turned out.

This summary does, however, show the number of general, intermediate and light machinery repairs each period, the number of tubes reset or part set and the total number of fire-box sheets applied, and thus affords as clear a statement of shop output as can be obtained without going into greater detail, and also, when totaled for all shops in a district, enables a fairly close estimate to be made, as to whether the required amount of shop work on the system is being obtained.

It may be objected to, and with good reason, that a classification of this nature does not define the repairs received with sufficient accuracy to allow of fair comparisons to be drawn; as, for instance, one engine receiving No. 1 machinery repairs may require a new driving axle, a new pair of cylinders and frame taken down, while another receiving the same class of repairs may not require any of those especial items, or that a fire-box sheet may mean a flue sheet on one engine and a side sheet on another; but the only answer can be that any system going into such details would become so complicated as to defeat its object, and that such information must be obtained from the work report and not from the statement of shop repairs.

The latter is and should be a general summary, and the explanation of the amount of work performed can safely be left to the man whose output is not fairly allowed for.

One important point to consider is the allowance that should be made for the size of the engines repaired, as it is obviously true that the large and heavy locomotives now being used can not be either repaired or maintained for the same amount as smaller engines. From the point of view of the shop alone probably the best comparative unit for this purpose would be the weight of the engine, as this determines the amount of material it is composed of and is consequently a measure of its cost and also of the cost of the labor necessary to repair it. There are, however, many reasons for using a unit for repairs which is also to be used for general purposes, and your committee feels that, while not strictly included in this subject, reference may be made to the tractive power mile introduced by Mr. A. A. Goodchild, when Auditor of Statistics on the Canadian Pacific Railway, which has many advantageous features. On that road the tractive power is expressed in the usual way as a percentage, an engine shown as 100 per cent having a draw-bar pull of 20,000 pounds calculated at 85 per cent of the boiler pressure. An engine having a tractive power of 30,000 pounds is shown as making 1.5 100 per cent miles for each mile it runs, and the cost of repairs is calculated both for the locomotive mile and the 100 per cent locomotive mile. This unit is also used in a number of other ways, but the above example will illustrate its principle. The test of two or more units is their approximation to the truth, and in comparing those suggested for the comparison of locomotive repairs, the miles, the engine ton-mile and the tractive power, or, as it may be called, the 100 per cent mile, the mile may be first eliminated, since with engines varying in weight in the ratio of three to one it is evidently inaccurate. Considering the 100 per cent mile as against the engine ton-mile, if two engines weigh the same, but one is a consolidation, the other a ten-wheeler, the consolidation will cost more to repair. On the engine ton-mile basis the allowance would be the same, on the 100 per cent mile basis the consolidation will obtain a greater allowance, which will to a certain extent compensate for its greater cost of upkeep. If, again, two engines of equal weight are

compared, one passenger and one freight, the freight engine will cost the larger sum per mile. On the 100 per cent mile basis this is partly compensated for by the increased tractive power and this unit may therefore be said to be the closer. Your committee does not consider it necessary to define the tractive power which constitutes 100 per cent, as that is unimportant, provided it is known and allowed for; but in view of the merits of the tractive power or 100 per cent mile as a unit it would recommend that the same unit be used in allowing for the output of a shop. By including this factor the statement of engines receiving repairs at any point in place of showing the number of engines actually receiving No. 1, 2 and 3 machinery repairs, etc., would show the equivalent number of 100 per cent engines receiving such repairs and a 50 per cent engine counting as 0.5 and a 150 per cent engine as 1.5 100 per cent engines turned out, and so on, and your committee then considers that the output of the various shops would be measured as closely as is practicable without objectionable complication.

H. H. VAUGHAN, Chairman,
A. E. MITCHELL,
R. QUAYLE,
D. VAN ALSTYNE,
Committee.

MONTREAL, CANADA, May 8, 1906.

THE PRESIDENT: Gentlemen, you have heard the report. What is your pleasure?

MR. G. W. WEST (N. Y. O. & W.): I move that the report be received and the subject opened for discussion.

MR. H. A. GILLIS (Amer. Loco. Co.): I am particularly struck by the report on classification of engine repairs. The first question which always comes to my mind when I see any report or any report is sent to me is, What is the value of the report? What use am I going to make of it, or anybody is going to make of the report? As I understand it, the principal object of the classification is to try to determine what your various shops are doing, and the relative merits of the work done on the various divisions. I do not think you obtain it at all by any kind of classification of repairs. The amount of repairs made in a shop, and the number of engines turned out of a shop, depends a great deal on the quality of the repairs. That is one of the things which seem fallacious in that sort of report. That is not a theoretical proposition; it is a

practical proposition based on experience with various divisions. One man's reports might tend to show that he was a most energetic man. He had a large quantity of repairs being done on his engines, in fact probably twice as many repairs as the Master Mechanic on the opposite division. The majority of his engines were in the shop most of the time being repaired; on the other division, running right alongside of him, really a much harder division to run, this Master Mechanic had very few repairs to his credit. His engines were not in the shop being repaired, but out on the road doing service. These two men were afterward changed. The man who had the largest quantity of repairs and output in his shop was put on the other division, and within a few months the conditions were reversed. He still had the record on classification of repairs; he had a larger number of repairs, and his shop, as far as paper was concerned, was apparently giving better results in every way than the other man; but the fact was that the amount of mileage gotten out of his engines was nowhere near so good, nor was anywhere near the same number of ton-miles secured, pooled with engines of the other division, as in the case of the other man. I do not think you can tell anything about the work being done in any shop by a mere statement of the amount of its repairs. I know of another instance where two men were changed. In one case of repairs, Class 3 repairs, the number of these repairs going through the shop were about thirty-five to forty a month. Inside of two months the new man made a record of sixty a month and also had a large percentage of the power in the shop. What is the meaning of that? It is simply this — that in one case when the engine was repaired it was actually repaired and put in proper condition, but in the other case when it was repaired it was only half repaired, and when it went out on the road it broke down, and possibly after that as much repairs as ever had to be done on the engine. In the classification of repairs for these two divisions, the man who really did the poor work usually showed up the best. I do not think anything at all can be obtained in the way of really valuable information by simply classifying repairs as 1, 2, 3 and 4. I think the only way by which you can tell how your shops are going is, how they are maintaining a certain number of engines in running condition on the road, and the cost of the maintenance of these engines.

MR. G. W. WEST (N. Y. O. & W.): I want to indorse Mr. Gillis's statement. My experience has been similar to his, that the number of engines turned out by a shop is no indication of the real amount of work that is being done there. I was at one time a Master Mechanic on a trunk line, and was followed by a man who has now passed into the other world. He met me on a train about a year after he took the place and he wanted to know if I knew what our pay-rolls were when I was Master Mechanic of the road, and I told him that I did. He told me they were turning out double the engines, with the same amount of expenditure, that I had turned out when I was Master Mechanic of the road. I told him he was a good man, and if he was able to do that he ought to hold his position. Two or three years after that they abandoned eight or ten trains a day for want of motive power.

MR. WM. MCINTOSH (C. R. R. of N. J.): I would suggest for the conditions outlined by Mr. Gillis, that the information he desires could be readily determined if headquarters obtained comprehensive reports of the work done in detail. They would then very readily judge who was doing the galvanizing and who was doing straight work.

MR. T. H. CURTIS (L. & N.): The Louisville & Nashville road has abandoned the classification of locomotive repairs by numbers. We found this system could be galvanized, so to speak, and we have gone to the unit system of classifying repairs by a number of units. If an engine has Class 1 repairs, that is, $100 worth of repairs, Class 10 would be $1,000 worth of repairs, and Class 50 would be $5,000 worth of repairs. The Master Mechanic then putting on $1,000 worth of repairs gets credit for Class 10; $5,000 worth, Class 50. I find this is much better for the information of the Superintendent of Machinery and also the Vice-President and General Manager to have this system in vogue. They can tell more by the money spent than by the 1, 2, 3 classification of repairs.

MR. C. H. QUEREAU (N. Y. C.): I do not intend to criticize what Mr. Gillis and Mr. West have said, because such cases as they have mentioned are occurring right along. I believe if they will pursue the matter a little further, in conjunction with the

plan suggested by the committee, they will discover that a compilation of the cost per ton-mile will show up the true condition of affairs. The number of repairs turned out may not show who is galvanizing and who is not, but the cost per ton-mile will surely develop that feature.

In this connection it occurs to me it would be wise to have two bases on which to judge efficiency — one on which to judge the efficiency of the shop based on cost per ton of locomotives repaired, the other by which to judge the efficiency of the Division Superintendent of Motive Power or Master Mechanic, the cost per ton-mile. I think a little analysis will show both of these methods are very desirable. It may be thought it will add considerably to the cost of your statistics, but I think a little further consideration will show that is not well founded. It simply means another division.

MR. H. A. GILLIS: If that is the meat of this cocoanut, why have the shell at all? Throw the shell away and get at the meat, which is the cost per ton-mile. There is no use in having classifications unless you are going to make use of them. The question of the value of reports of classification of locomotive repairs was impressed upon me seriously at one time. I was called upon to sit up practically all night to make my weekly reports to the Superintendent of Motive Power. You can judge of my horror one Monday morning when I was in his office, and I saw the report which I had sat up pretty nearly all Saturday night to compile, lying on his desk, unopened. The stenographer took it up in my presence, and threw it unopened into the waste-paper basket. I said to him, "Excuse me, that is my weekly report." He said, "Oh, we never look at those."

MR. G. W. WILDIN (Erie): One object in having a classification of some kind for engine repairs is, that we may know when an engine leaves the shop about what service we may expect. The only way I know of to be certain of this is to have a classification showing the actual work performed on the engine while undergoing repairs, and if this work is honestly and intelligently reported we may feel quite certain that we know the general condition of our power and the service we will get.

MR. T. E. ADAMS (St. L. S. W.): We have an inspector at

our headquarters who never worked in the shops in the mechanical line, but was formerly in the tank gang. This man makes the closest inspection of any inspector we have ever had. When an engine goes in the shop he goes over the engine and reports all defects, making a list of them, after which he gives them to the roundhouse foreman who distributes them to the different departments. This is a very satisfactory way of taking care of engines in the pool. I believe in what Mr. Wildin says; we want to know about these things at the right time. We talk about the character of engines, this and that; the Master Mechanic walks through the shop and says, "We want that engine out next week"; "Why are you taking down the guides?" etc.

What we want is, when an engine comes out of shop, to have it bear inspection, as we always have our inspector go over the engines after they are turned out of the shop, and the attention of the Master Mechanic is called to irregularities that are found, and the same remedied. We believe there are a great many failures avoided by this system of inspection, both by having engines inspected in the roundhouse, as well as in shop work by a competent inspector. We do not believe that a large engine in heavy service, well taken care of, should necessarily be an expensive engine to maintain, if the work is done properly in the first place and good care is taken of the engine afterwards. The trouble frequently is that little things are found out of order and the engine allowed to run another trip. They keep up this kind of work until you get so many defects that the engine is in general bad repair. But if each line of repairs is taken up at the proper time and given the proper attention it has a wonderful effect in giving good service and furnishing engines promptly when the transportation department needs them.

THE PRESIDENT: We will give Mr. Vaughan an opportunity to close the discussion.

MR. H. H. VAUGHAN (Can. Pac.): I do not think the discussion is directed to this report at all. To begin with, I undertake to say that if Mr. Gillis visits our shop, the first question he would ask is, "How many engines do you turn out in a month?" We all know that about every railroad man asks that question.

MR. H. A. GILLIS: That is stereotyped.

MR. H. H. VAUGHAN: Yes, that is stereotyped. If you are running six or eight shops, every one looks around every month to see how many engines each shop is turning out. Is not that about so? You all want to know the shop output.

Every one has some sort of classification of repairs. In this report we have mentioned the fact that there is a certain amount of doubt as to whether the classification was advisable, but the committee was appointed to make the classification. I have used this classification for two years, and I find it works pretty conveniently. If we know that a shop is turning out six, ten or twenty, according to the shop, No. 1 machinery repairs every month, we have a fairly good run of what the shop is doing. We know they are calling for so many thousand dollars for labor per month. If the output begins to fall off we want to know why it is falling, and I think most of you would. We watch also the cost per mile of every engine going into the shop, but the shops are run on an allowance system, and we want to know the number of repairs each shop is turning out per month. If you go on the $100 unit plan, what do you know as to what the man is doing? If he is putting in $30,000 on repairs, he must turn out 300 units. A shop may cost twice as much in one year as it did in some previous year, and yet they may not be putting out any more work in proportion to the increase in cost. We want to know what is being done. We want to know, when an engine is overhauled, whether it is making the mileage which we expect it to make. We want to know whether tubes are reset, and whether work has been done to the fire box. This information, of course, can be secured through detailed reports, but I think the classification of shop repairs as treated in this report has a definite value. There is also another condition, where you have main shops receiving engines from any division, and you want to know how many engines the shop is turning out. On every railroad I have been connected with, every one has manifested a keen interest in turning out so many engines from the shop. It has generally been a pretty keen object to get out so many engines every month. There are many shop superintendents who do not watch closely the number of engines put out every month, but no doubt most of the Master Mechanics pay considerable attention to that matter.

What the classification gives you is a more logical method of enumerating these repairs than the money system, or the system of numbering 1, 2 and 3 machinery. When I was on the Lake Shore we had a 1, 2, 3, 4, 5 classification, and it came to be pretty difficult to distinguish between No. 3 and No. 4. We had certain combinations. An engine would come in with part of 3 and part of 4, and it was generally put to No. 3, and the office would take it up with the Master Mechanic and ask why he did not call it No. 4. There was a good deal of trouble on account of such matters, and we finally got down to a plain classification, No. 1 and No. 2, for light and heavy machinery, and No. 1-F and No. 2-F. "F" meant flues reset. That worked very well, but we had engines coming in for a considerable number of odd jobs. They did not have the tires turned, but there were specific repairs; defect repairs, such as a broken crank pin, or something of that kind, and these repairs were called No. 3. If you know the shop is turning out so many 1, 2 and 3 machinery repairs every month, you have a rough definition of the shop output. It does not take the place of other statistics, but is a useful supplement. I do not think the ton-mile is of any use in locomotive repairs. They will vary 3 or 4 to 1, on ton-mile basis. They will not vary as much on the engine-mile basis, and will vary much less on the 100 per cent engine-mile basis than on the engine-mile basis. We have been working the 100 per cent engine-mile basis for several years, and find the repairs compare closely with the tractive power of the engine. The closer the unit is the better, and this is the best unit we have discovered so far. Our passenger power is figured on that basis, and also our switch power. In engines varying in tractive power in proportions of 3 to 1, that unit applies pretty nearly correctly and is a fairly good test of the unit.

My idea of this report was that the first two sections were of real importance, to distinguish between engines in service and those under repair. We are criticized right along on the percentage of engines in service and out of service. I presume that all roads are criticized on that point. I think it would be of general advantage to adopt a standard classification determining when an engine is considered in service and when it is considered out of service for repairs. I also think, in view of a probable

separation of running repairs, and especially repairs on performance sheets in future, a separation I feel personally is going to come, it would be to our advantage now to standardize a distinction between running and shop repairs, so that in interchange performance sheets we will know what it means. It will be interesting to know what it is per mile for running repairs. Of course, the shop repairs are separate, but the distinction now varies from $10 to $300.

The committee has proposed a classification for engines in service and engines out of service, and another one for running repairs. I think this convention should either object to them or adopt them, and if they adopt them they should be referred to the American Railway Association for use on standard performance sheets and mileage sheets. Every now and then there is an exchange of information of this character, and it would be interesting to know that the statistics are made up on a uniform basis.

MR. G. W. WEST (N. Y. O. & W.): I move that twenty-four hours be adopted as the limit distinguishing between engines in service and those under repairs, and that $100 be adopted as the limit distinguishing between running and shop repairs. (Motion carried.)

MR. G. R. HENDERSON: I move that the subject be closed.

THE PRESIDENT: We will have to allow the remainder of the program set for to-day to go over until to-morrow, in order to fill our engagement with the Baldwin Locomotive Works.

THE SECRETARY: Inasmuch as we have left over a good deal of the work on the program for to-day, I suggest that the meeting be opened to-morrow morning at 9 o'clock instead of 9:30 o'clock, as we have a large program and should begin at least a half-hour earlier.

THE PRESIDENT: Unless there is objection that will be agreed to.

Meeting adjourned until 9 o'clock Wednesday morning.

WEDNESDAY'S SESSION.

President Ball called the meeting to order at 9:15 o'clock.

THE PRESIDENT: The first in order this morning is the report of the Committee on Engine House Running Repair Work on Locomotives.

In the absence of any members of this committee the report was read by the Secretary. It is as follows:

REPORT OF COMMITTEE ON ENGINE HOUSE RUNNING REPAIR WORK ON LOCOMOTIVES.

To the Members:

The subject assigned your committee to report on is rather indefinite in so far as the latter part is concerned, for we are asked, "with what machine tools and hand tools should a roundhouse be equipped to get the best results?" If we had been told the size of the roundhouse, or the number of engines housed in a given time, we would have had something to work on, but as this information is lacking, will base our report on the assumption that it is a fifty-stall house and that one hundred and fifty engines have to be taken care of in the twenty-four hours.

In the first place we are asked, "What is the best practice for doing this work (running repairs on locomotives), handling reports, etc., made by foremen, engineers, road foremen and inspectors," and would say that a system as outlined below will give the maximum results with the minimum delay and expense. It is very necessary to know what work has to be done on an engine before it arrives in roundhouse, so that, if for the drop pit, it can be run there without delay, or, if any heavy repair work is necessary, it can be run in a stall convenient to machine shop, which will save time of machinists.

A system of Engineers' Work Reports (samples submitted) and engineers educated to report their work fully and intelligently; these slips should be deposited in a box or other receptacle, located centrally, and preferably close to foreman's office, so that the man in charge of handling them, and distributing the work, can do so and keep in touch with the foreman.

A system of writing out the work on separate slips and giving it to the proper man, who signs same and returns it to the gang foreman when work is done, has many advocates and enables a close check to be kept on improper repairs. Whichever system is used, it is absolutely necessary to know who has done the work, for future reference.

When an engine arrives in the roundhouse, the inspector should at once make an examination of it, reporting all the work found, on the regular Engineers' Slip, but signing his own name and adding the word

"Inspector," so that a check can be kept on the engineers to see if they are looking over their engines properly.

If any repairs are necessary, the gang foreman should have his men ready to make them, so as to avoid any delay; if for washing out, the steam and water should be blown off into a proper receptacle and hot water used for washing out and filling up. Great care should be exercised so that the machinists are not sent to an engine that is to be washed out, unless they can do their work without interruption. If it is necessary to grind in boiler checks, renew stay bolts, or do other work that can only be done when the water is out of the boiler, advantage should be taken of this opportunity.

On some roads the Road Foreman of Engines uses a regular blank for reporting work that he finds while riding on engines. This report should be turned in so that it can have attention while engine is out of service, and we recommend that work reported by a road foreman should have particular attention paid to it, as his discipline is hurt to a great extent, and his usefulness impaired, if no notice is taken of his reports.

There are so many different conditions existing in this country that it is a difficult matter to draw a hard and fast line as to how engine-house running repairs should be taken care of. On some roads the water conditions are good, so that boiler work is almost unknown. On others, the amount of boiler work fixes the time an engine is out of service. On some roads, with poor coal, it is not unusual to change grates nearly every trip, while on others the coal is of such good quality that grate troubles are almost unknown. However, in all cases, the prime object of a roundhouse organization is to quickly take care of the necessary repairs, and to do so the force must be so built up that when an engine arrives in the house all concerned must know what to do and how to do it, having such tools at their command that experience teaches are most necessary.

The location of a roundhouse of the size being considered has to be taken into account. If in close proximity to the main shop, less machine tools may be necessary, but where entirely self-supporting, a proper outfit should be supplied to take care of anything that may come along.

In addition to the small tools owned and carried by the various mechanics, we recommend the following:

1 48 by 48 inch by 8 foot planer.
1 24-inch lathe.
1 40-inch heavy drill press.
1 20-inch drill press.
1 emery wheel.
1 16-inch bolt lathe.
1 22-inch shaper.
1 bolt-cutter to take up to 2 inches.
1 36-inch boring mill.
1 hydraulic or screw press for driving box brasses, rod bushings, etc.

Suitable cranes around engines and drop pits, either supported by posts or roof, so as to take care of air pumps, steam chests, front end doors,

driving boxes and other heavy parts. The lifting on and off of cabs is something that should not be overlooked.

A driving-wheel drop pit capable of taking care of at least two engines at a time.

1 engine-truck drop pit capable of taking care of at least two engines at a time.

1 tender-truck drop pit, if trucks are suitable for wheels to be dropped.

2 gasoline or oil tire heaters, with proper-sized hoops and burners; can be used for straightening frames, etc.

1 rotary valve-seat planer of sufficient size to take the largest-sized seats.

1 boring bar for piston-valve bushings.

1 cylinder boring bar.

4 piston-rod pullers, various sizes.

12 differential chain hoists.

4 ½-inch grab chains.

4 ⅝-inch grab chains.

12 pinch bars.

12 heavy capacity jacks, 35 or 40 ton, hydraulic or lever.

12 screw jacks for holding up work.

4 lever-journal jacks.

2 lever jacks for pilot and tank work.

2 air hammers made out of pipe or old hydraulic jacks for driving out rod and frame bolts.

6 air motors, various sizes, two to be end motors for close work.

4 crosshead lifters.

2 spring pullers.

3 close chisel bars.

6 long chisel bars.

4 two-wheel trucks for moving material.

1 blacksmith forge.

1 set ratchets and rollers for valve-setting.

2 four-wheel rod trucks.

1 portable arrangement for hydrostatic test.

1 steam-gauge tester.

1 complete set of twist drills, ¼-inch to 2-inch.

1 small breast drill.

1 complete set standard reamers, ¾-inch to 2-inch.

1 pipe vise.

1 complete set of standard taps, ¼-inch to 2-inch.

Cold chisels, as many as necessary.

1 complete set of pipe cutters, dies and taps from ¼-inch to 3-inch; sufficient adjustable pipe wrenches to accommodate the force of men that the work requires.

6 each, open wrenches, ⅜ by ⅝ inch, to 1¼ by 1¼ inches.

2 each, large-size open wrenches, up to largest size nut on locomotives.

6 mauls, various weights, 8 to 16 pounds.

12 handle punches, ¾ to 1¼ inches.

2 pneumatic hammers for boilermakers, chipping, etc., caulking tools, etc.

1 complete set stay-bolt reamers and taps; in fact, complete outfit for stay-bolt, flue and grate work.

The above are about the most important factors in roundhouse work, but we would advocate sufficient chisels, gauges, hack saws, files, scrapers, straight-edges, etc., to accommodate the force maintained at each roundhouse in order that one man may not be held up on a job waiting for another man to get through with some small tool.

Each roundhouse should have a separate toolroom of its own, with a man in charge, both day and night, to handle the tools on a check system; otherwise it will be impossible to maintain roundhouse tools.

In addition to above on engine-house running repairs on locomotives, the following good suggestions were brought out in discussion of this paper at the Western Railway Club meeting, held at the Auditorium hotel, Chicago, Tuesday evening, March 20, 1906, and are endorsed by your committee.

The use of a floating or hospital gang in roundhouse, to which gang will be turned over the heavier jobs so as to get engines into service quickly, instead of having the work drag along with various men being put on and taken off according to the exigencies of the service; this system will often enable an engine to be kept out of back shop and increase the mileage between shoppings.

A long master wedge for drawing piston rods into crossheads before the regular wedge is applied.

A small bolt lathe mounted on a truck and run by electric or air motor, for use around an engine where new rod, truck or cylinder bolts are being fitted, to save running back and forth to machine shop.

Always keep one engine on blocks undergoing moderately heavy repairs so that machinists can be kept busy at all times when work in the roundhouse falls off temporarily. It is claimed that work done in this manner costs more, but where business fluctuates it is a good proposition.

The neglect of running repairs causes engine failures to increase and also decreases the life of an engine between shoppings.

A hydraulic press operated by a screw, for forcing out rod bolts, etc., saves bolts from being upset when hit by a sledge.

An inverted "Y," with the upright leg slotted, which is used for removing heavy cylinder heads, the method of operating being to stand the "Y" against cylinder head, with feet on floor and stud through slot, the nut being put on and tightened so that when cylinder-head nuts are removed head can be "walked" away and stood ready for application.

H. T. BENTLEY, Chairman,
P. MAHER,
F. T. HYNDMAN,

CHICAGO, ILL., April 25, 1906. *Committee.*

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CHICAGO & NORTH-WESTERN RAILWAY CO.

No._____ Report of condition of Engine No._____ after careful inspection on arrival at _____ M. _____ 190___

Engine is in good condition, with the following exceptions:_____

_____

_____

_____

_____

Condition of Right Injector_____

Condition of Left Injector_____

Condition of Blow-off Cock_____

Condition of Engine and Tender Brakes_____

Safety Valve lifts at _____ lbs.
Safety Valve seats at _____ lbs.

_____ Engineer.

NOTE.—Engineers must carefully inspect their engines after each trip, and report their condition on this form, whether needing repairs or not. They will be held responsible for every defect not reported. No attention will be given to verbal reports or reports not signed by engineer.

(FACE.)

Repaired at _____

On _____ 190___

The following repairs were made on Engine No._____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Repairs made by _____
Name of workmen in charge of work

Approved by _____
Foreman Roundhouse.

NOTE.—Workmen in charge of work will sign for repairs done, and hand this statement to Foreman of Roundhouse, who will approve and forward same to MASTER MECHANIC.

(BACK.)

Form M 61.

The New York, New Haven & Hartford R. R. Co.

MOTIVE POWER DEPARTMENT.

ROAD FOREMAN'S REPORT.

_____190___

Engine No_____ Train _____

Rode on engine, from_____

To _____

Name of Engineer_____

Name of Fireman _____

No. of cars in train_____

No. of air brakes on cars working_____

No. of air brakes on cars cut out_____

Condition of brakes_____

Steaming qualities of engine_____

Ability to handle train_____

Quality of coal_____

Where obtained_____

Attention to oiling_____

Pops relieve at_____

Cleanliness of Terminal Wiping_____

Cleanliness of Fireman_____

Attention to Signals_____

Locomotive is good for_____months' service.

Condition of:

Firebox _____

Flues _____

Ashpan and Dampers_____

Brick Arch _____

Jacket _____

Bell and Whistle _____

Driving Boxes _____

Trailing Boxes_____

Wedge_____

Rod Brasses _____

Eccentrics_____

Slide Valves _____

Pistons _____

Packing_____

Motion _____

Injectors and Lubricators_____

Signal and Marker Lamps _____

Brass inside of cab_____

Woodwork inside and out of cab _____

_____

Road Foreman.

NOTE: General remarks on opposite side.

Form M 60.

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD CO.

Report of Repairs Needed to Engine No.....

Engineer_____ Fireman_____

Arrived: Train_____Time_____Date_____190

DESCRIPTION OF REPAIRS.	MADE BY	DATE.
Packing		
Piston Rods or Valve Stems		
Main Rods		
Side Rods		
Crosshead		
Eccentrics		
Valve Motion		
Pipe Work		
Cocks, etc		
Boiler Work		
Grates and Ash Pan		
Engine Trucks		
Driving Boxes		
Tender Trucks		
Springs		
Air Brakes		
Injectors		
Does Engine steam well?		
If not, why?		
Is Engine blowing?		
If so, what blows?		
Pressure at which pops open?		
Main reservoir pressure		
Train line pressure		
Other work needed		

Date_____190 _____Engine-House Foreman.

THE PRESIDENT: Unless there are objections, the paper is before you, open for discussion.

MR. C. A. SELEY (C. R. I. & P.): Mr. President, we have considerable business to do at this last day of the convention, and these are all interesting papers, and deserving of discussion, yet we can not discuss them. I move that the discussion on this paper be closed, and that all other papers submitted, where the committees are not present, be merely read by title and the discussion closed. (Motion carried.)

THE PRESIDENT: The next in order is an individual paper entitled, "The Modern Locomotive Injector," by Mr. Strickland L. Kneass.

MR. STRICKLAND L. KNEASS: Mr. President, instead of taking the time of the Association by reading this paper in detail, I will, with your permission, simply make a short extract of it as I go along, calling the attention of the members to certain parts which I would like emphasized.

In the first place, the object of the paper is to give some data relative to the performance of the boiler feeding apparatus, and to give suggestions in regard to the sizes of connections, method of handling, and also a statement of the limitations. The data which are here given are all based upon experiments and not upon theoretical conditions. All formulæ and all abstract statements have been omitted as far as possible, so as to make the paper, if possible, of practical value to members.

THE MODERN LOCOMOTIVE INJECTOR.

BY MR. STRICKLAND L. KNEASS.

To the Members:

1. The position occupied by the Injector as one of the essential accessories of a locomotive renders the discussion of the conditions which govern its action of special interest to railroad officials. Of equal importance is a knowledge of its limitations, while data as to its performance under modern conditions of high pressure and severe service are necessary to an intelligent choice of size and style for a given class of work. The tests which are given in this paper cover an unusually wide range of conditions, and indicate the capabilities as well as the limitation of an injector.

2. In view of the wide field covered, it was necessary that special care be taken with all attachments, so that the results would not be impaired by

mechanical defects, nor by insufficient areas of supply and discharge; the efficient feeding of the boiler is often seriously reduced by leaks in the suction pipe and hose, incorrect design of tank valve and strainer, or impurity of the water and steam supply. It is desired to lay special stress upon the importance of this part of the subject, which will be considered in detail under the following heads: The Supply, the Injector, and The Delivery.

THE SUPPLY.

3. The water supply is forced through the narrow entrance to the combining tube of the injector by atmospheric pressure, the available head being the difference between the suction height at the water branch and the vacuum within the combining tube. It is necessary that this entrance area be small, so that the water shall have a high velocity during its time of contact with the steam, but the suction pipe and connections should be of ample size, or the resultant friction will reduce the effective head at the entrance to the combining tube. The pipe diameters recommended for various nominal sizes of injectors are given in the following table:

TABLE I.

Nominal Size of Injector	7	8	9	10	11	12
Iron (Inside) ...	1½ inches	2 inches	2½ inches	2½ inches	3 inches	3 inches
Copper (Outside)	1¾ "	2¼ "	2¾ "	2¾ "	3¼ "	3¼ "

(Non-Lifting Injector may use one size smaller.)

4. The areas of the tank valve and connecting castings should be greater than given in Table I. The perforations of the straining plate should not exceed 3-32 inch diameter, and their total area should be three times that of the suction pipe; the tank should be frequently cleaned and free from ashes and coal. An illustration of the condition in which a straining plate is sometimes found is given in Fig. 1.

5. The suction pipe should be short and direct, with easy bends, and preferably of copper. The injector should be placed at or 6 inches above the upper level of the water in the tank. The effect of increasing the height of lift is apparent from the following table:

TABLE II.

EFFECT OF HEIGHT OF LIFT.

Height of Lift.	Steam Pressure,	Water Supply.	Capacity in Percentages.
2 feet	200 pounds	75°	100%
6 "	" "	"	95%
8 "	" "	"	80%

The suction pipe, hose and connections should be absolutely tight under 30 pounds pressure.

7. The condition of the steam supply is also of great importance; it should be dry and saturated, and conducted through pipe passages large enough to allow full boiler pressure at the steam nozzle of the injector. Wet steam tends to cut the valve seats and nozzles, superheated steam to reduce the mechanical efficiency and the capacity. As an illustration of the cutting action of wet steam, Fig. 2 is shown. The steam passed over

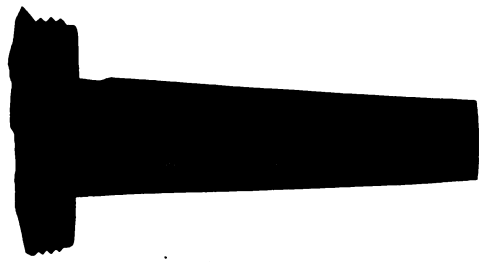


FIG 2.

the exterior surface with high velocity, abrading the metal at the softer spots where the eutechtic alloy was in evidence or where the microscopic pores were most numerous. The action was so severe as to form an annular under-cut, while at another point the nozzle is perforated.

THE INJECTOR.

8. The action of the injector depends primarily upon the impact of a condensible gas upon its own liquid; the directing and receiving nozzles should be designed and constructed according to the curves that govern the flow under given conditions of velocity and pressure; owing to the high velocities of both the actuating gas and the resultant jet, departure from the correct contour causes rapid and unnecessary wear. The surfaces should be smooth and hard, the metal homogeneous, and without microscopic evidence of porosity, characteristic of all tertiary or quarternary alloys.*

9. The essential characteristic of a boiler-feeding device is certainty of action, because the failure of a locomotive due to a defective injector, although serious enough in its consequences, can not compare with the injury and loss of life which may result from an exposed crown sheet. Of secondary, but also of great importance from an economical point of view, are the range, efficiency, etc. These desirable points are emphasized under the headings: "Construction," "Performance of an Injector."

CONSTRUCTION.—The design of an injector should be simple and constructed with the fewest parts, as it is easier to understand and cheaper to repair, and the stock of renewal parts is reduced to the minimum.

*This subject is treated at length in "Physical Characteristics of certain Bronzes for Steam Uses," Kneass, Proc. Frank. Ins. Jan. 1905.

It should contain a single-seated lever starting valve. Double steam seats are difficult to keep in line, leak more quickly and are more expensive to repair.

All valve seats subject to pressure should be heavily constructed and easily removable.

The overflow valve should be self-opening. It should not be subject to the pressure of the boiler; it should open freely if the injector "flies off." The heater cock should be convenient of access. All parts should be perfectly interchangeable.

PERFORMANCE.— No hand adjustment of the water supply should be required to prevent wasting, for any change of boiler pressure. It should operate at 15 pounds steam and give its highest capacity at or above the working boiler pressure. The minimum capacity should not be greater than 50 per cent of the maximum, for there are few cases where a continuous feed is not the most economical, both for fuel consumption and for the life of flues. It should be able to feed continuously with either a light or heavy train.

It should re-start automatically, for the water supply is liable to be temporarily interrupted by the swash of low water in the tender or by accidental adjustment of the feed below the minimum capacity. In either case the injector should re-prime automatically. Further, automatic re-starting renders the action positive when running at night or when the injector is placed outside of the cab.

It should be economical in the use of steam, so that when the locomotive is heavily loaded, starting the injector will not pull down the boiler pressure. Starting a No. 10 injector reduces the tractive power from 95 to 150 horse-power, depending upon the design of the injector, tubes and nozzles.

When the steam pressure is 200 pounds, the injector should operate positively with a water supply at a temperature of at least 100°; a still higher limiting temperature is advantageous, if the performance of the injector is not sacrificed.

10. Comprised under both the above heads is the wear of the internal parts; at 200 pounds pressure, the velocity of the steam at the smallest part of its nozzle is 1,500 feet per second, increasing to 2,800 feet per second at the terminal flare and reaching 3,847 feet per second at the time of impact with the water.

Fig. 3 shows the effect upon a nozzle of large particles of foreign material in the water supply, due to improper cleaning of the tank, the absence of a straining plate or a plate in which the perforations are too large. Not only is the interior surface cut entirely out of shape at the point

FIG. 3.

where the steam impinges, but the outer walls of the tube are bent outward by the force of the impact.

11. To illustrate the necessity of using the correct curves for fluid motion in the design of the tubes, Fig. 4 is shown. Incorrect alignment, combined with the attrition of dirty water moving at a high velocity, are the chief causes of wear. The defect at the middle of the tube always appears with improper design; instead of being distributed evenly throughout the whole divergent curve, the wear is localized, causing rapid deterioration of the delivery tube and inefficient action of the injector.

12. The cutting action of silt or dirt in the water supply is proportional to the velocity of the carrying jet, just as is the case with a polishing or abrading wheel. If the tubes are correctly designed, the converging and diverging curves corresponding to the lateral contraction and expansion

FIG. 4.

of the jet, the longest service will be given. But to reduce the cutting action, it is obviously advantageous to maintain as low a velocity in the delivery tube as is consistent with the ability to feed the boiler; this can only be obtained when the minimum weight of steam is used by the injector per gallon of water delivered; the amount of steam used

can be measured by the temperature of the feed entering the boiler compared with that of the water supply. The higher the temperature of the delivery, the greater the excess of steam used, and the higher the velocity of the jet and consequent cutting action.

A table giving the relation of delivery temperature to the velocity of the jet is given below:

TABLE IV.

VELOCITY OF JET IN DELIVERY TUBE, FOR TEMPERATURE OF BOILER FEED, STEAM PRESSURE 200 POUNDS, WATER SUPPLY 65°.

Temperature Boiler Feed.	Approximate Velocity.		Temperature Boiler Feed,	Approximate Velocity.	
	Ft. per Sec.	Ft. per Min.		Ft. per Sec.	Ft. per Min.
160	230	13,800	250	315	18,900
175	238	14,280	275	365	21,900
200	255	15,300	300	455	27,300
225	280	16,800	325	580	34,800

When it is remembered that the surface speed of a grinding wheel is only between 5,000 and 6,000 feet per minute, the enormous velocities noted in Table IV and the effect of abrasive foreign material in the water supply will be appreciated.

13. When the water supply contains lime-bearing salts, both the exterior and interior surfaces of the tubes become coated; however, if the tubes are continually submerged in cold water, the precipitation of scale is largely prevented. A properly designed non-lifting injector is very serviceable with water of this kind; during operation, water from the supply may be admitted directly to the overflow chamber and tubes; when the injector is shut off, closing the waste valve keeps the injector body flooded with cold water, condensing all leakage from the steam valve.

THE DELIVERY.

14. The delivery should be conducted through two check valves: First, the main check bolted or screwed to the boiler shell, preferably supplied with a superimposed stop, to permit the complete withdrawal of the main check valve and its seat from the casing without reducing the pressure of the boiler. Second, a supplemental check, placed close to the injector. The reason for advocating a check valve in the pipe line is that with the present fixed standards of exterior dimensions of the injector and its branches, it is practically impossible to design a satisfactory valve at or near the delivery tube, and contained within the injector body, which will be convenient of access without breaking the delivery connection, or will be durable under high boiler pressures.

15. The delivery pipe need not be as large as the suction, as there is always ample forcing power in an injector to overcome a valve and pipe resistance of from 10 to 50 pounds counter-pressure. Where the water

supply contains carbonate or sulphate of lime, it is advantageous to use a larger pipe, on account of the coating of scale which soon forms on its interior surface when the main check leaks. An illustration of the effect of scale is given in Fig. 5, where the actual diameter is reduced from 1¼

FIG. 5.

inches to ⅝ inch, the photograph being taken from a section of the branch pipe of a locomotive of a Texan railroad.

METHOD OF TESTING.

16. The high pressure tests which are recorded in the diagrams were made with steam taken from a 300 horse-power Babcock & Wilcox boiler, capable of carrying 300 pounds to the square inch; tests at the lower pressures were made with the same injector and tubes, connected to a low pressure boiler in order to avoid superheating the steam by excessive throttling. A separator was placed in the steam pipe, lagged and carefully drained. The water in the supply tank between point levels was weighed and continually re-checked; all thermometers and gauges were accurately calibrated; observations and readings were taken by three operators. As soon as a test was made, it was plotted on a temporary diagram to determine its correspondence with previous results; if found to vary from the general trend of the curves it was repeated, and errors were thus eliminated as far as possible. In the final diagrams, the curved lines connect the individual observations and are extended above and below the limit of experiments according to the general tendency of the established curves. In each diagram the abcissas indicate the gauge steam pressures, and the vertical ordinates gallons per hour, degrees Fahrenheit, etc. The points on the curves at which the experiments occur are denoted by small circles.

DESCRIPTION OF INJECTOR.

17. A sectional view of the tested injector in its elementary form is shown in Fig. 6. From the delivery tube *c*, the other parts are proportioned, and its diameter is 10.5 mm. (0.41 inch) at the smallest part of

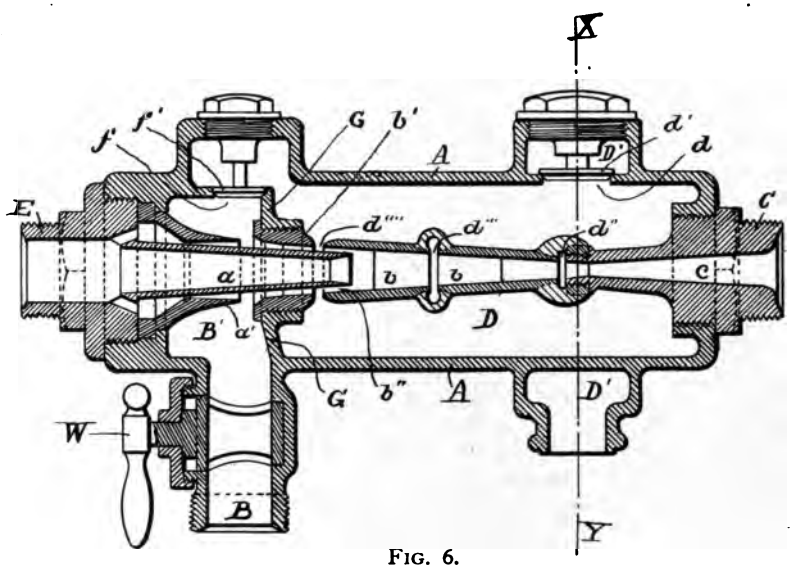


FIG. 6.

the bore. A feature of the design is the continuous acceleration of the water between the suction branch and the smallest diameter of the delivery tube; the primary movement is given by the partial vacuum due to the condensation of the lifting steam jet *a'*; the second, by the impulse of the steam discharge from this nozzle; the third increment is due to the low pressure within the condensing chamber of the forcing combining tube *bb*, and the final impulse, which adds sufficient velocity to the combined jet of water and condensed steam to pass through the contracted area of the delivery tube *c*, is due to the impinging of the steam from the forcing steam nozzle *a*. The resultant high velocity is then reduced to that of the water in the boiler feed-pipe, by the parabolic divergent flare of the delivery tube *c*, which is so proportioned that the negative acceleration, or retardation, shall be constant.

18. In this form of injector the two actuating steam jets are placed in the same axial line, so that the combining tube of the lifting steam nozzle discharges its supply of water directly into the receiving end of the forcing combining tube. Owing to the peculiar design and proportions of the nozzles the capacity of either set of tubes is much less than that of the combined apparatus; this is due to the fact that when the two sets of tubes are working in conjunction, the pressure within the receiving end of the forcing combining tube is considerably below that of the atmosphere and at times is 20 inches vacuum, increasing the flow through the lifting tubes. These conditions obtain as the steam pressure rises until the

increased discharge of steam from the forcing nozzle requires a greater supply of water than can be obtained from the lifting tubes, so that while the forcing jet is passing the apertures *d''*, *d'''*, which open into the overflow chamber *D*, a partial vacuum is produced in the overflow chamber; some of the water in the suction pipe *B* and water chamber *B'* will therefore raise the supplemental inlet valve *f'* and enter the overflow chamber *D*, submerging the openings of the forcing combining tube. The jet in this tube will then draw the supplemental water supply from the overflow chamber *D* into the combining tube *bb* and carry it through the delivery tube *c*, thus materially increasing the capacity of the injector.

19. At lower steam pressures, below 120 pounds, the capacity of the lifting set is sufficient to supply the forcing tubes, and the supplemental inlet valve *f'* is inactive.

20. The apertures d'', d''' and *d''''* in the forcing combining tube *bb* have a further function, namely, that of allowing free discharge of steam from both nozzles without producing a back pressure in the suction chamber *D'*; this permits the injector to re-start automatically. Under all conditions of operation, there is a partial vacuum in the suction pipe, for the overflow valve *d'* and its connecting outlet passage are of ample size to permit free outflow of exhaust steam with all steam pressures.

EXPLANATION OF DIAGRAMS.

21. Diagram I shows graphically the maximum and minimum capacities at steam pressures ranging from 2 pounds per square inch to 325 pounds, when the temperature of the water supply is 50°, 65°, 80°, 95°, 110°, 125° and 140°; the injector in each case operating with the overflow valve free to open, to permit automatic re-starting. The vertical scale indicates gallons per hour from 0 to 4,500, and the horizontal scale, steam pressures from 0 to 325 pounds.

22. From Diagram I can also be obtained the range of capacities for any desired steam pressure and water supply temperatures, by subtracting the values given by the curved lines. For example, when the boiler pressure is 200 pounds, and the water supply 65°, the maximum capacity is 4,068 gallons per hour and the minimum 1,846, giving a range of 2,222 gallons. The overflowing temperature is that point at which no regulation of the water supply will prevent the emission of drops of water at the overflow; it therefore corresponds to the temperature at which the maximum and the minimum capacities coincide. This is indicated by the pointed junction of the maximum and minimum lines on the diagram for any given condition. For example, at 275 pounds boiler pressure, the overflowing temperature is 80°; at 175 pounds, 110°; points not shown on diagram may be interpolated, but are more clearly shown in Diagram II, where the temperature tests are specially plotted.

steam, the minimum capacity is 100 per cent of the maximum at 80°, as shown by the overflowing temperature in Diagram II, or the pointed intersection of the 80° line of Diagram I.

28. The widest range is obtained, as should be supposed, with coldest water, namely 50°, and is at 100 pounds steam, when the minimum is 35 per cent of the maximum. At modern locomotive boiler pressures 200 pounds, water supply 65°, the minimum capacity is 45 3-10 per cent of the maximum, giving an actual permissible variation of the capacity of 2,222 gallons per hour.

29. The mechanical efficiency is measured by the ratio of the weight of supply water to the weight of steam used. The ratio is shown in Diagram IV, where the vertical scale represents pounds of supply water delivered per pound weight of steam, and the horizontal scale, gauge pressures in pounds per square inch. As was noticed on the previous diagrams, the higher pressures do not show the action to be as effective as at low steam. It is probable with an ideal injector, or one in which the entering areas of water and steam could be modified to suit every variation of pressure, the curve on Diagram IV would extend its parabolic tendency upward until it approached tangency with the vertical ordinate of 0 pressure. The values shown, however, are exceptionally good, and indicate a high efficiency for this kind of steam operating device. At 200 pounds pressure, 10.7 pounds of water at 65° are drawn from the supply tank and delivered for each pound weight of steam taken from the boiler.

30. In conclusion it may be said that the same set of nozzles was used in all tests, from 2 pounds steam pressure to 250 pounds, a far wider range of pressures than required in practice.

MR. ANGUS SINCLAIR: I move that this paper be received for publication in the Proceedings. (Carried.)

THE PRESIDENT: The paper is open for discussion. If there is no discussion, a motion to close the discussion is in order.

MR. J. F. WALSH (C. & O.): Mr. President, I move that the discussion be closed. (Carried.)

THE PRESIDENT: The next in order is the report of Committee on Locomotive Lubrication.

MR. G. E. PARKS: Mr. President, Mr. Bronner asked me to read the report, owing to his absence.

REPORT OF COMMITTEE ON LOCOMOTIVE LUBRICATION.

GENERAL CONSIDERATION OF SUBJECT:

1. With reference to high steam pressures and superheated steam.

2. How far may we economize in lubrication, both internal and external?

3. The consideration of standard fittings for lubricators.

4. The consideration of sight feed lubricators versus pumps for internal lubrication.

To the Members:

This subject is of vital importance to every railroad company, and, as the information at hand does not warrant us to draw definite conclusions in all cases, the report should be considered as a preliminary one.

The committee, in investigating the subject, divided the work so that each member could devote his time to one phase of the subject. Consequently the report represents the combined effort of the committee.

1. A Proper Lubricant for High Steam Pressure and Superheated Steam.

For locomotives with steam pressures as high as 225 pounds, or those using superheated steam, the temperature of which is as high as 600° F., the ordinary valve oil has been found by experience to be quite satisfactory. The problem is to deliver the oil in proper quantities, to the place where needed.

2. Economy in Internal Lubrication.

In order that the engine parts may perform their work properly and without undue wear or heating, lubrication here should not be stinted. Dry valves and cylinders mean rapid wear of the surfaces of contact in the steam chest and cylinders, besides excessive trouble with the valve motion parts. An attempt to get even at the minimum of oil used for internal lubrication is apt to result in hot or slipped eccentrics, and broken eccentrics, eccentric straps, links, transmission bars, rockers, valve stems, and connection pins, in addition to the trouble just mentioned. Aside from increased machine friction, the performance of the engine is affected. Hard running valves cause a derangement in steam distribution; and worn packing in valve chambers, cylinders, or at rods, causes a loss due to leakage.

With the slide valve locomotives, there is not so much danger of these troubles becoming excessive, because the jar of the reverse lever is such

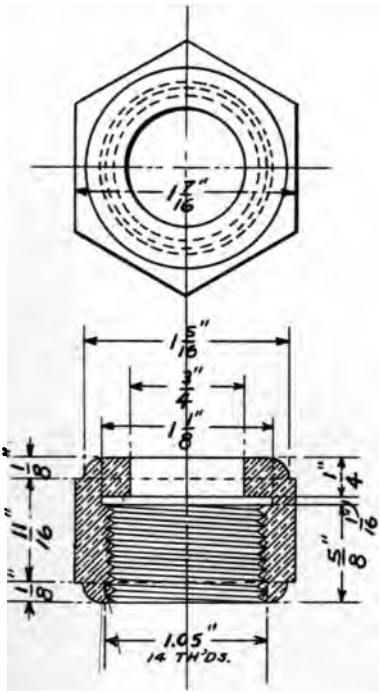


FIG. 2.

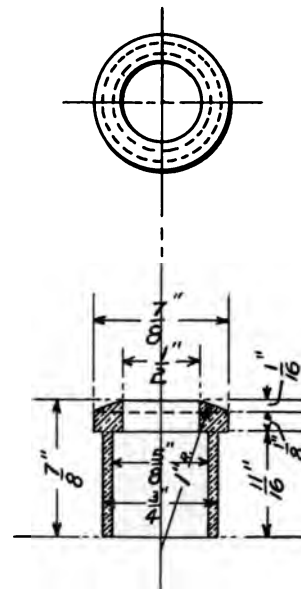


FIG. 3.

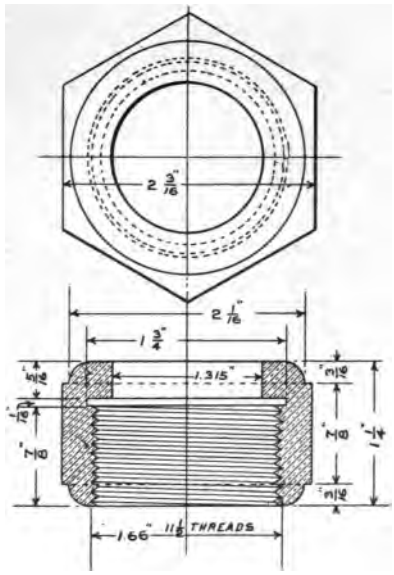


FIG. 4

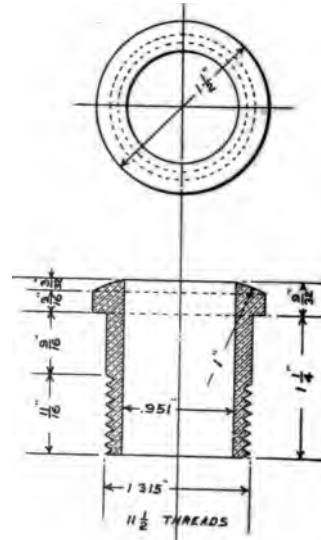


FIG. 5.

(a) Reduces engine failures due to heated journals and pins.
(b) Reduces cost of lubrication.
(c) Reduces cost of labor incident to inspection, cleaning and renewals of lubrication packing,
(d) Reduces delays incident to oiling.
(e) Reduces cut journals incident to oil lubrication.
(f) Possibly produces a slight increase in machine friction.

4. The Consideration of Standard Fittings for Lubricators.

To facilitate the use of different lubricators on the same railroad we would propose a standard as to relative location of holding arm shoulder and oil and steam connection joint faces; and a system of standard fittings and joints for all connections. Fig. 1 illustrates the standard proposed for location for connection of joints and holding arm. This is thought to provide ample variation to the lubricator companies, and, at the same time, to bring the connections near enough together so that by bending the pipes slightly lubricators made to this recommendation shall be interchangeable. Figs. 2, 3, 4, and 5 illustrate the standard for pipe joints and fittings. Fig. 6 illustrates standard holding arm proposed.

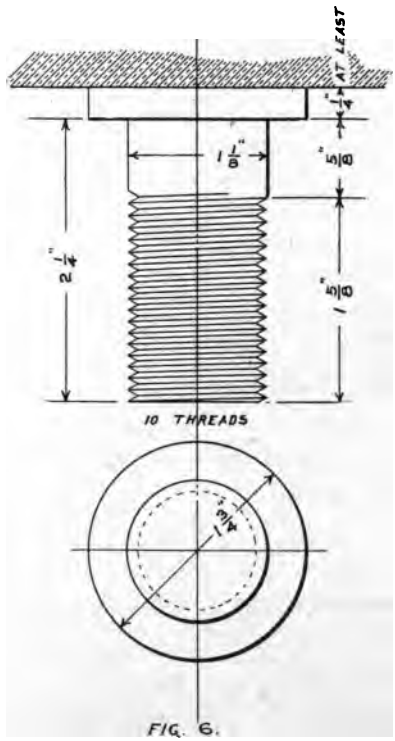


FIG. 6.

5. LUBRICATORS VERSUS PUMPS.

Data collected from twelve different systems would seem to indicate that pump lubricators of whatever description are still in a state of imperfection, and that quite as good results have been obtained by using the ordinary sight feed lubricator, even on superheated steam locomotives.

The indulgence of the Association is asked for on the incompleteness of the report.

Your committee would suggest that the recommendations in Part No. 4 — Consideration of Standard Fittings — be referred to letter ballot for adoption as standard, and would ask that the committee be continued.

E. D. BRONNER, Chairman,
R. F. KILPATRICK,
C. KYLE,
R. D. SMITH,
Committee.

DETROIT, MICH., May 24, 1906.

THE PRESIDENT: Gentlemen, before discussing this paper, we have a topical discussion on "Grease vs. Oil in Driving-box Cellars," to be opened by Mr. F. H. Clark. As this refers to lubrication, it would perhaps be just as well to have this topical discussion with the discussion of the regular report. We also have a report of tests to determine the loss of power resulting from friction in the machinery of a modern passenger locomotive using grease. This report could also be discussed at the same time. If some one will make a motion to that effect we can save considerable time by handling these three subjects together.

MR. G. W. WEST (N. Y. O. & W.): Mr. President, I move that the subject of Grease vs. Oil in Driving-box Cellars and the report referred to be considered with the report. (Carried.)

THE PRESIDENT: The regular paper is open for discussion. Before opening the discussion, I would like to have Mr. Clark make a few remarks on the subject of this topical discussion. Then we can continue the regular discussion.

MR. F. H. CLARK (C. B. & Q.): Mr. President, the committee has said nearly everything I have to say with reference to

grease lubrication. We have been lubricating locomotive driving journals by means of grease for three or four years, and, generally, with very good success. We at one time had an engine fitted up with grease lubricators, and had considerable trouble with the engine. It ran hot, and we finally took the devices off, and on investigation found that the springs used for holding the grease in contact with the journal were too light. After replacing them with springs of suitable strength we had no further trouble. Our experience has been about as indicated by the committee which has just reported. We find that the use of grease reduces engine failures due to heated journals, that it reduces delays incident to oiling, reduces cut journals, but as to the cost of lubrication, I have no definite information, and am not certain as to the reduction in cost of labor incident to inspection, cleaning, and renewals of lubrication packing. Neither have we any information as to the increase in machine friction. We have not found it necessary to reduce the tonnage of any of our engines on account of the use of grease.

THE PRESIDENT: Professor Goss, will you kindly present your report on loss of power resulting from friction?

PROF. W. F. M. GOSS: Mr. President and Gentlemen: This report of the laboratory was made to Mr. Deems. I suppose that I am requested to read it because it is in my handwriting.

REPORT OF TESTS TO DETERMINE THE LOSS OF POWER RESULTING FROM FRICTION IN THE MACHINERY OF A MODERN PASSENGER LOCOMOTIVE.

To the Members:

Following the work of the Committee on Locomotive Front Ends, and while the New York Central engine was still at Purdue University, Lafayette, Ind., some tests were made at the request of Mr. J. F. Deems, General Superintendent Motive Power, New York Central Lines, to determine the resultant loss of power from the friction in the machinery of a modern passenger locomotive. The results of these tests proved of so much interest that Mr. Deems has consented to their publication before the Association. The report of Professor Goss is herewith submitted.

ENGINEERING LABORATORY, PURDUE UNIVERSITY.

LAFAYETTE, IND., May 16, 1906.

Mr. J. F. Deems, General Superintendent Motive Power, New York Central Lines, Grand Central Station, New York City:

DEAR SIR;— 1. In response to your request and with the approval of the Master Mechanics' Committee on Locomotive Front Ends, tests have been made to determine the loss of power resulting from the friction in the machinery of a modern passenger locomotive, when axle-boxes and pins were lubricated by grease and oil respectively. The tests involved New York Central Atlantic type passenger engine No. 3929, which had been sent to the Purdue laboratory for the accommodation of the Master Mechanics' Committee on Locomotive Front Ends. They were conducted by the regular laboratory staff of the University, assisted by such extra attendants as had been employed in connection with the Master Mechanics' work already referred to. The work was in charge of Prof. W. O. Teague, Assistant Professor of Experimental Engineering, assisted by Mr. L. E. Endsley, instructor in charge of the locomotive laboratory, and by certain members of the Senior class.

2. *The engine* as received at the laboratory was equipped for grease lubrication upon pins and axles. The rods were fitted with compression cups and the axles with Elvin grease pads. This equipment was used throughout the progress of the front-end tests and at no time did any trouble arise from the lubrication.

Following the Master Mechanics' work, the special tests upon grease were run, after which the engine was jacked up, the axle-boxes removed, the rods taken down and all journals and boxes carefully examined. The journals presented a fine glazed surface and were without blemish. The axle-boxes which had served to bring the engine from Buffalo to Lafayette, 500 miles, and in running 1,500 miles in the laboratory, a total of 2,000 miles, presented a good surface in which the file-marks of the original fitting were discernible at several points. Portions of the brasses were highly polished and contained so little lubricant that the finger was not stained in being rubbed over them, nevertheless, they had evidently had sufficient lubrication to protect the boxes from injury. The appearance of the boxes of the main-axle is shown by Fig. 1 and that of the Elvin grease pads used in connection therewith, by Fig. 2. The grease pads, after the mileage already indicated, showed a thickness of approximately two inches.

During the process of dismantling the grease equipment, Mr. A. G. Elvin, representing the Franklin Company and the inventor of the Elvin grease pad, was in attendance at the laboratory. After an inspection of all parts removed, he readily agreed that the conditions which had prevailed during the tests with grease could be accepted as entirely satisfactory to him and to the advocates of grease lubrication.

FIG. 1.

At the completion of the examination the process of making the changes necessary to permit the use of oil was undertaken by machinists sent from the Big Four shops at Indianapolis by the courtesy of Mr. Garstang. The rod-cups were converted into pin-feed cups for oil, and oil channels and oil-ways were cut in the axle-boxes to agree with the drawing of your company, S-7949, supplied by Mr. F. M. Whyte, Mechanical Engineer. That all conditions might agree with the practice of the New York Central Lines, wool waste was sent from Indianapolis to pack the boxes and an order was given by Mr. Garstang upon the local Big Four roundhouse for engine oil. It appeared later that this order upon the roundhouse was misinterpreted and that car oil was supplied instead of engine oil, with the result that an attempt to run at high speed led to a

FIG. 2.

hot axle-box. The boxes were taken down and found to have suffered little damage, were re-touched and put back again. The engine was run a few days at slow speed for the purpose of wearing them to bearings, after which the formal tests proceeded. By the use of proper oil, all further trouble with hot boxes was avoided.

3. *The Test.* The machine friction of a locomotive mounting upon a testing-plant is the difference between the power developed in the cylinder and the power delivered at the draw-bar. This difference represents the power required to drive the pistons, cross-heads, main-rods, coupling-rods, driving-axles, eccentrics, link motion, rockers, valve-stems, and valves. Tests to determine the machine friction therefore involve simultaneous observations at the cylinders and draw-bar.

In anticipation of the tests and to avoid possible chances for errors, the rails under all truck wheels were slipped to give new points of contact both upon the rail and the wheel. This was repeated before beginning the tests with oil.

It is to be noted also that the location of drivers with reference to supporting wheels was absolutely the same for both the grease tests and the oil tests. This was assured by the process of changing the axle boxes, by which the location of the supporting wheel and the length of the draw-bar remained undisturbed.

The tests were made at speeds of 20 miles, 50 miles and 60 miles an hour. The 20-mile tests usually resulted in the development of from 400 to 500 horse-power; the 50-mile tests in the development of between 700 and 800 horse-power, while for the 60-mile tests the power was usually in excess of 800 horse-power. These conditions I believe to fairly represent those of service.

In outlining the tests it was assumed that the frictional resistance of the machinery of a locomotive would depend somewhat upon the temperature of the parts which are lubricated, and in consequence of this assumption it was thought best to make a distinction between the observations which were made when the machinery was comparatively cold, and those which were made after it had been warmed by its own motion. In the data, therefore, the tests are grouped as "cold tests" or tests which had their beginning when the machinery was started cold, and "hot tests" or tests which were made up of observations taken after the machinery had been warmed up by running. The cold tests ordinarily embrace observations made during the first half of each day's run. The hot tests are made up of the later observations of the same days.

4. *The Results* show that with slow speed the friction of the machinery with grease lubrication is greater hot than cold, while at higher speeds results are contradictory, but the differences are in no cases great. The results also show that with oil the friction under all conditions of running is higher when the machinery is hot than when cold, though in this case the differences are very slight.

Accepting the oil lubrication as a basis of comparison it appears that at 20 miles an hour the loss of power resulting from the use of grease is slight, so small in fact as to be almost negligible, but as the speed is increased the loss is increased and at 60 miles per hour it amounts to

from 140 to 160 horse-power. The equivalent coal loss, assuming four pounds of coal per horse-power hour, is something more than 500 pounds per hour. A summary of results in form permitting easy comparisons, is set forth in Table I.

TABLE I.

SPEED OF ENGINE 20 MILES AN HOUR.

1.	Pounds pull at the draw-bar necessary to overcome friction of the engine.		
	Cold start	Grease 1,578	Oil 1,435
	Hot start	Grease 2,222	Oil 1,549
	Average	1,900	1,492
2.	Tractive force lost by use of grease.....		408
3.	Horse-power lost		21.8
4.	Coal lost per hour run (assuming 4 pounds per horse-power hour)		87.2

50 MILES AN HOUR.

1.	Pounds pull at the draw-bar necessary to overcome friction of the engine.		
	Cold start	Grease 1,862	Oil 555
	Hot start	Grease 1,628	Oil 780
	Average	1,745	667
2.	Tractive force lost by use of grease.....		1,078
3.	Horse-power lost		143.7
4.	Coal lost per hour run (assuming 4 pounds per horse-power hour)		574.8

60 MILES AN HOUR.

1.	Pounds pull at the draw-bar necessary to overcome friction of the engine.		
	Cold start	Grease 1,727	Oil 655
	Hot start	Grease 1,804	Oil 873
	Average	1,765	764
2.	Tractive force lost by use of grease		1,001
3.	Horse-power lost		160.2
4.	Coal lost per hour run (assuming 4 pounds per horse-power hour)		640.8

5. *Concerning the detailed statement of data accompanying.* A detailed statement of the various observations is set forth in Tables II to VII, inclusive, an index of which is as follows:

Table II — Oil tests at 20 miles per hour.
Table III — Oil tests at 50 miles per hour.
Table IV — Oil tests at 60 miles per hour.
Table V — Grease tests at 20 miles per hour.
Table VI — Grease tests at 50 miles per hour.
Table VII — Grease tests at 60 miles per hour.

In these tables the significance of hot and cold start may be seen by reference to column II, which gives the total number of minutes the engines had been operating at the time each particular observation was made.

The values for friction throughout these tables are expressed in two terms, namely, the total equivalent pull at the draw-bar (col. VIII), which is the value carried forward into the summary as presented in Table I, and the friction per driving axle (col. IX), values which are directly comparable with the results published by the Pennsylvania Railway Company.

A comparison of individual observations (Tables II to VII) will disclose some variations of values. This probably arises from two causes: first, the frictional resistance of journals undoubtedly varies from moment to moment, due to minor causes affecting the distribution of lubrication. In so far as such causes enter, their effect upon the result is legitimate. A second cause is to be found in the acceleration, positive and negative, of the engine. For example, when the engine is increasing its speed instantaneous observations at cylinders and draw-bar will show the indicated power to be greater than normal, and similar observations taken when the engine's speed is diminishing will show the indicated power to be less than normal. The measurement of friction derived from these observations will, in the first case, be too high and in the second case, too low. It has been attempted to have inequalities of this sort neutralized by the abundance of the observations recorded, for in the long run the average value will be a true value.

Finally, attention should be called to the fact that in Tables II to VII, tests on a number of different days are grouped together; thus, referring to Table II it will be seen that there is first presented a series of results, seven in number, which are assumed to represent the performance of the engine cold. Following this are two different series of results. The first of these began after the engine had been operating 84 minutes and continued until the engine had been run 105 minutes; while the second series began when the engine had been running 51 minutes and continued until it had been run 118 minutes. These two latter series were made upon different days. This fact makes the close agreement in results the more significant.

Respectfully submitted,

W. F. M. Goss.

TABLE II.

OIL—20 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per minute.	Miles per hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	13	80	18.4	445	9,065	7,870	1,195	597
2	18	90	20.7	486	8,803	7,550	1,253	626
3	23	79	18.2	443	9,138	7,720	1,418	709
4	28	77	17.7	441	9,323	7,720	1,603	801
5	33	79	18.2	442	9,123	7,650	1,473	736
6	38	78	17.9	443	9,254	7,610	1,644	822
7	43	78	17.9	427	8,913	7,440	1,473	736
Average for oil, engine cold							1,435	718
1	84	80	18.4	468	9,533	7,700	1,833	916
2	87	80	18.4	474	9,654	8,040	1,614	807
3	90	79	18.2	469	9,671	8,060	1,611	805
4	93	80	18.4	476	9,693	7,890	1,803	901
5	96	80	18.4	481	9,795	8,100	1,695	847
6	100	81	18.6	404	8,137	6,610	1,527	763
7	105	81	18.6	391	7,862	6,310	1,552	776
8	51	45	10.5	198	7,160	6,690	470	235
9	58	80	18.4	415	8,452	7,240	1,212	606
10	63	79	18.2	420	8,667	7,280	1,387	693
11	68	79	18.2	425	8,763	7,330	1,433	716
12	73	81	18.6	459	9,236	7,660	1,576	788
13	78	81	18.6	453	9,109	7,640	1,469	734
14	83	81	18.6	449	9,037	7,500	1,537	768
15	88	83	19.1	494	9,707	7,850	1,857	928
16	93	82	18.9	484	9,612	7,920	1,692	846
17	98	84	19.3	498	9,673	8,180	1,493	746
18	103	81	18.6	483	9,718	7,960	1,758	879
19	108	80	18.4	468	9,544	7,970	1,574	787
20	113	80	18.4	470	9,570	8,000	1,570	785
21	118	80	18.4	477	9,713	7,850	1,863	931
Average for oil, engine hot							1,549	774

TABLE III.

OIL—50 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute.	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	13	227	52.2	756	5,427	4,600	827	413
2	19	235	54.1	757	5,249	4,675	574	287
3	21	228	53.5	727	5,196	4,910	286	143
4	24	221	50.8	743	5,477	5,035	442	221
5	27	219	50.4	710	5,281	4,640	641	320
Average for oil, engine cold							554	277
1	48	218	50.1	781	5,842	4,850	992	496
2	51	227	52.2	829	5,951	4,738	1,213	606
3	69	238	54.7	872	5,974	5,056	918	459
4	72	234	53.8	805	5,606	4,712	894	447
5	77	219	50.4	759	5,646	4,480	1,166	583
6	109	220	50.6	797	5,908	5,000	908	4 4
7	112	225	51.8	800	5,797	4,925	872	436
8	115	231	53.1	771	5,439	4,647	792	396
9	118	230	52.9	780	5,526	4,608	918	459
10	123	224	51.6	813	5,915	5,000	915	457
11	123	231	53.1	802	5,661	5,269	392	196
12	126	242	55.6	786	5,293	4,813	480	240
13	129	218	50.1	758	5,668	5,028	640	320
14	132	225	51.7	698	5,057	4,512	545	272
15	135	225	51.7	716	5,189	4,487	702	351
16	138	222	51.0	780	5,729	4,901	828	414
17	141	241	55.4	751	5,077	4,696	381	190
18	144	223	51.3	737	5,388	4,910	478	239
Average for oil, engine hot							780	390

TABLE IV.

OIL—60 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	II.	IV.	V.	VI.	VII.	VIII.	IX.
1	13	227	52.2	756	5,427	4,600	827	413
2	19	235	54.1	757	5,249	4,675	574	287
3	21	228	53.5	727	5,196	4,910	286	143
4	24	221	50.8	743	5,477	5,035	442	221
5	27	219	50.4	710	5,281	4,640	641	320
6	36	257	59.1	762	4,835	4,270	565	282
7	38	274	63.0	863	5,133	4,190	943	471
8	40	256	58.9	771	4,908	4,180	728	364
9	42	258	59.4	779	4,921	4,160	761	380
10	44	266	61.2	809	4,957	4,210	747	373
11	46	258	59.4	771	4,871	4,180	691	345
Average for oil, engine cold							655	327
1	154	265	61.0	805	4,950	3,945	1,005	502
2	156	259	59.6	794	4,998	3,910	1,088	544
3	158	260	59.8	859	5,384	4,285	1,099	549
4	160	251	57.8	797	5,173	4,480	693	346
5	172	260	59.8	839	5,265	4,260	1,005	502
6	174	262	60.3	886	5,514	4,190	1,324	662
7	177	269	61.9	885	5,360	4,280	1,080	540
8	179	259	58.6	834	5,247	4,260	987	493
9	181	259	58.6	841	5,291	4,170	1,121	560
10	36	257	59.1	762	4,835	4,270	565	282
11	38	274	63.0	863	5,133	4,190	943	471
12	40	256	58.9	771	4,908	4,180	728	364
13	42	258	59.4	779	4,921	4,160	761	380
14	44	266	61.2	809	4,957	4,210	747	373
15	46	258	59.4	771	4,871	4,180	691	345
16	150	272	62.5	845	5,061	3,840	1,221	610
17	161	258	59.3	772	4,880	4,260	620	310
18	164	261	60.0	784	4,897	4,130	767	383
19	167	263	60.5	767	4,753	4,220	533	266
20	169	249	57.2	737	4,825	4,340	485	242
Average for oil, engine hot							873	436

TABLE V.

GREASE—20 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute.	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	3	63	14.5	146	3,769	2,000	1,769	884
2	6	84	19.3	235	4,555	2,550	2,005	1,002
3	8	80	18.4	266	5,429	3,485	1,944	972
4	10	84	19.3	283	5,487	3,480	2,007	1,003
5	20	89	20.5	516	9,458	8,775	683	341
6	21	87	20.0	513	9,609	8,590	1,019	509
7	31	81	18.6	429	8,630	7,100	1,530	765
8	33	78	17.9	447	9,338	7,680	1,658	829
9	34	80	18.4	478	9,747	8,170	1,577	788
10	37	81	18.6	481	9,674	8,159	1,515	757
11	39	80	18.4	477	9,719	8,229	1,490	745
12	44	82	18.9	492	9,782	8,138	1,644	822
13	49	81	18.6	477	9,591	8,157	1,434	717
14	54	80	18.4	468	9,537	7,856	1,681	840
15	59	81	18.6	431	8,664	7,336	1,328	664
16	64	81	18.6	486	9,782	8,158	1,597	798
17	69	83	19.1	490	9,629	8,004	1,625	812
18	74	82	18.9	488	9,695	8,153	1,542	771
19	79	80	18.4	474	9,662	8,113	1,549	774
20	84	83	19.1	500	9,821	8,162	1,659	829
21	89	82	18.9	495	9,841	8,151	1,690	845
22	94	82	18.9	486	9,655	8,070	1,585	792
23	99	82	18.9	483	9,626	8,040	1,586	793
24	104	81	18.6	484	9,743	8,109	1,634	817
25	109	83	19.1	499	9,788	8,118	1,670	835
26	114	83	19.1	491	9,632	8,077	1,555	777
27	119	83	19.1	490	9,599	8,066	1,533	766
28	124	81	18.6	488	9,825	8,166	1,659	829
29	129	82	18.9	492	9,787	8,135	1,652	826
30	134	81	18.6	489	9,840	8,124	1,716	858
31	139	83	19.1	501	9,843	8,123	1,720	860
32	144	82	18.9	478	9,509	8,122	1,387	693
33	149	84	19.3	500	9,697	8,162	1,535	767
34	154	87	20.0	505	9,464	8,031	1,433	716
35	159	86	19.8	513	9,722	8,080	1,642	821
Average for grease, engine cold							1,578	789

TABLE V.—Continued.

GREASE—20 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per minute.	Miles per Hour		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	56	83	19.1	349	6,857	4,950	1,907	953
2	58	83	19.1	346	6,810	4,650	2,160	1,080
3	59	80	18.4	346	7,087	4,910	2,177	1,088
4	61	80	18.4	335	6,830	4,595	2,235	1,117
5	62	78	17.9	317	6,621	4,390	2,231	1,115
6	66	78	17.9	448	9,353	7,260	2,093	1,046
7	68	83	19.1	478	9,413	7,500	1,913	956
8	69	80	18.4	433	8,826	6,750	2,076	1,038
9	71	82	18.9	531	10,562	8,190	2,372	1,186
10	72	81	18.6	522	10,498	7,810	2,688	1,344
11	75	80	18.4	498	10,134	7,635	2,499	1,248
12	78	82	18.9	541	10,762	8,170	2,592	1,296
13	79	85	19.6	558	10,697	8,120	2,577	1,288
14	80	84	19.3	578	11,221	9,100	2,121	1,060
15	81	79	18.2	512	10,561	8,000	2,561	1,280
16	83	82	18.9	536	10,653	8,260	2,393	1,196
17	85	83	19.1	540	10,609	8,130	2,479	1,239
18	88	83	19.1	536	10,520	7,985	2,535	1,267
19	90	84	19.3	549	10,668	8,270	2,398	1,199
20	94	87	20.0	576	10,796	8,600	2,196	1,098
21	99	80	18.4	466	9,497	7,570	1,927	963
22	104	83	19.1	508	10,006	7,810	2,196	1,098
23	109	77	17.7	494	10,446	8,180	2,266	1,133
24	114	84	19.3	532	10,330	8,110	2,220	1,110
25	119	82	18.9	531	10,557	8,270	2,287	1,143
26	124	84	19.3	536	10,405	8,080	2,325	1,162
27	129	85	19.6	525	10,066	8,070	1,996	998
28	134	79	18.2	506	10,433	8,270	2,163	1,081
29	139	81	18.6	515	10,372	8,220	2,152	1,076
30	144	85	19.6	539	10,332	8,200	2,132	1,066
31	149	83	19.1	522	10,224	8,225	1,999	999
32	154	82	18.9	531	10,544	8,365	2,179	1,089
33	91	87	20.0	553	10,330	8,074	2,256	1,128
34	92	84	19.3	540	10,483	8,084	2,399	1,199
35	94	80	18.4	511	10,398	8,364	2,034	1,017
36	96	82	18.9	521	10,354	8,284	2,070	1,035
37	99	81	18.6	517	10,396	8,313	2,083	1,041
38	102	81	18.6	524	10,553	8,273	2,280	1,140
39	105	82	18.9	524	10,416	8,282	2,134	1,067
40	108	81	18.6	519	10,436	8,232	2,204	1,102
41	111	81	18.6	503	10,119	8,161	1,958	979

TABLE V.—Continued.

GREASE—20 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute.	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
42	114	80	18.4	517	10,520	8,121	2,399	1,199
43	117	82	18.9	525	10,445	8,150	2,295	1,147
44	120	81	18.6	515	10,362	8,180	2,182	1,091
45	184	83	19.1	509	9,991	7,890	2,101	1,050
46	185	82	18.9	506	10,057	7,940	2,117	1,058
47	186	79	18.2	496	10,230	8,000	2,230	1,115
48	187	53	12.2	334	10,276	8,000	2,276	1,138
49	192	79	18.2	493	10,152	8,120	2,032	1,016
50	193	80	18.4	492	10,031	7,840	2,191	1,095
51	194	79	18.2	507	10,461	8,250	2,211	1,105
52	195	80	18.4	506	10,311	8,210	2,101	1,050
Average for grease, engine hot							2,222	1,111

TABLE VI.

GREASE—50 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute.	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	3	63	14.5	146	3,769	2,000	1,769	884
2	6	84	19.3	235	4,555	2,550	2,005	1,002
3	8	80	18.4	266	5,429	3,485	1,944	972
4	10	84	19.3	283	5,487	3,480	2,007	1,003
5	15	222	51.1	775	5,683	3,375	2,308	1,154
6	16	228	52.5	796	5,684	3,785	1,899	949
7	18	223	51.3	765	5,595	3,820	1,775	887
8	21	224	51.5	772	5,619	3,565	2,054	1,027
9	26	225	51.8	733	5,309	3,640	1,669	834
10	27	225	51.8	717	5,193	3,570	1,623	811
11	30	222	51.1	749	5,491	3,525	1,966	983
12	35	222	51.1	738	5,412	3,640	1,772	886
13	40	222	51.1	764	5,601	3,660	1,941	970
14	45	225	51.8	779	5,646	3,925	1,721	860
15	50	225	51.8	723	5,231	3,810	1,421	710
16	54	178	40.9	560	5,124	3,220	1,904	952
Average for grease, engine cold							1,862	931
1	55	230	52.9	751	5,321	3,750	1,571	785
2	58	232	53.4	748	5,257	3,630	1,627	813
3	61	227	52.2	732	5,255	3,629	1,626	813
4	63	222	51.1	724	5,319	3,539	1,780	890
5	66	225	51.8	750	5,425	3,358	[2,067	1,033
6	70	225	51.8	786	5,694	3,758	1,936	968
7	75	226	52.0	748	5,399	3,997	1,402	701
8	80	226	52.0	706	5,093	3,936	1,157	578
9	85	230	52.9	737	5,223	3,735	1,488	744
Average for grease, engine hot							1,628	814

TABLE VII.

GREASE—60 MILES PER HOUR.

Serial Number.	Minutes Engine had Run Previous to Observation.	Speed.		Indicated Horse-power.	Tractive Force.		Friction. Pounds Pull at the Draw-bar.	
		Revolutions per Minute.	Miles per Hour.		Equivalent to Indicated Power.	Observed.	Total for Engine.	Per Driving Axle.
I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
1	16	221	50.8	778	5,743	4,100	1,643	821
2	18	255	58.7	838	5,350	3,523	1,827	913
3	20	260	59.8	813	5,095	3,126	1,969	984
4	22	258	59.3	785	4,959	3,129	1,830	915
5	24	257	59.1	777	4,929	3,211	1,718	859
6	29	258	59.3	769	4,855	3,159	1,696	848
7	34	258	59.3	782	4,937	3,066	1,871	935
8	39	263	60.5	753	4,663	3,103	1,560	780
9	44	258	59.3	741	4,676	3,240	1,436	718
Average for grease, engine cold							1,727	863
1	166	257	59.1	750	4,754	3,030	1,724	862
2	168	260	59.8	734	4,595	2,910	1,685	842
3	170	257	59.1	769	4,876	3,030	1,846	923
4	171	253	58.2	755	4,864	3,110	1,754	877
5	172	254	58.4	765	4,904	3,150	1,754	877
6	174	247	56.8	794	5,238	3,330	1,908	954
7	175	251	57.7	769	4,988	3,370	1,618	809
8	177	240	55.2	759	5,154	3,120	2,034	1,017
9	178	239	55.0	757	5,163	3,250	1,913	956
Average for grease, engine hot							1,804	902

In concluding his report Professor Goss said: One thousand pounds at the drawbar when the locomotive is developing 30,000 to 40,000 pounds is a very small percentage and it is for that reason at slow speeds the power equivalent is small, but as the speed becomes high and the maximum drawbar force which the locomotive can develop becomes reduced to 6,000 or 7,000 pounds then the 1,000 pounds absorbed by the grease friction in excess of that required by oil becomes relatively large.

THE PRESIDENT: These subjects are now open for discussion.

MR. G. W. WEST (N. Y. O. & W.): I would ask Professor Goss if, at any time during the test, the journals lubricated by oil showed any evidence of cutting and heating, and whether any comparisons were made between a journal running hot under oil lubrication as against one running cool under a grease lubrication. It seems to me that we have something besides the loss of power to consider in the use of grease; we certainly have freedom from train delays, and on a road where eighteen or twenty cars is a good load for a 100-ton engine it has never been found necessary to reduce our tonnage on engines running with grease lubrication. We have found it reduces our cost of lubrication and we get a great deal better mileage on engines using grease than with those lubricated by oil.

MR. W. G. WALLACE (D. M. & N. Ry.): Since the adoption of grease as a lubricant for driving journals we have not found an increased fuel consumption nor necessity for a reduction of tonnage. On the other hand we have made a better coal record, for the reason that time is not consumed in oiling that must afterwards be made up. The additional friction caused by the use of grease must be subtracted from the drawbar pull, which, if as great as stated, would seem that a reduction in weight of train should necessarily follow. It would be desirable to know if the loss shown in the tests from the use of grease is verified in practice.

MR. G. W. WEST (N. Y. O. & W.): I would like to say in connection with this matter something that I neglected to say before; our engines have made a better coal record; tests made on coal consumption prove that a very large proportion of

coal consumed in a round trip is while engines are standing at terminals or on side track. More miles and with the same amount of lubrication per ton of coal would be made with engines well lubricated than those lying still repairing axles and making other repairs due to cut journals or poor lubrication.

MR. M. H. WICKHORST (C. B. & Q.): The object of any kind of lubricant is to keep the metal surfaces apart so that there is no actual metallic contact. A lubricant itself has some friction in all cases, but the idea is to have the friction of the lubricant less than the friction of the metallic contact. If we take mechanism of very light weight — we will say as in a watch, for instance — the friction of a lubricant is so big that it is better to have no lubricant there at all, it actually retards the movement of the very light parts; but as we increase the load we have to interpose some lubricant, generally oil, and with very light machinery a light oil is used or the power used up in the friction of the lubricant itself is excessive. As we get to heavier machinery, for instance a locomotive, and keep on increasing the weight on the bearing surface, it is necessary to increase the viscosity of the liquid in order that the surfaces will not actually come in contact, but the friction of the lubricant itself keeps on increasing. That necessarily must be the case. The fact seems to be about this, that with the big locomotives we are running it is simply necessary to use this heavier lubricant in order to successfully keep the surfaces apart. That seems to be about the fact of the case. At any rate experience seems to show it is necessary to continually get a heavier lubricant in order that the surfaces do not actually grip; but that necessarily must result in increased internal friction of the lubricant itself. We must, in all cases, have a lubricant sufficiently viscous to keep the surfaces apart. If it means a loss of 100 h.-p. at high speed we simply have to stand that expense to keep the surfaces apart and avoid excessive heating. That there is this extra friction is, I think, shown by the fact that we have found it impracticable to use any metal for bearing metal in large locomotives that is softer than bronze. We require a phosphor bronze or something harder to successfully stand the heat. Soft bronze or Babbitt will run very successfully with oil in light power, but with heavy power and grease

lubrication the heat at the bearing surfaces is sufficient to cause them to distort very much and flow out, and for that reason we have not been able to use the softer metal successfully with greases.

MR. G. R. HENDERSON: The inference drawn from this report would be, in a measure, that oil was not as good a lubricant as grease. I have known a number of cases where the substitution of grease for oil, especially on crank pins, reduced the number of hot pins fully fifty per cent. The hot pin means not only delay to the engine, but loss of metal in turning the pin and boring the brass, and we should bear this in mind, for although there may be more actual friction, the grease gives much better practical results.

MR. P. H. PECK (C. & W. I.): My experience with grease is that while the brasses on the rods wear faster, we put up with that for the comfort that we have; in lubricating with grease we have less delays to our engines than in lubricating with oil.

MR. T. E. ADAMS (St. L. & W. S.): I would say, for the information of the convention, that we use grease on driving-boxes, eccentric rods, front ends of main rods, etc., with splendid success. We occasionally have a hot driving-box with grease. For instance, an engine will come in perfectly cool, and apparently has plenty of grease in the cellar. It leaves the terminal point, and in a run of twenty-five miles has a hot driving-box and the grease would be gone out of the cellar. We tried to ascertain the reason for this, and came to the conclusion that possibly the friction between the hub and the box was the cause of the grease going out of the cellar so suddenly, and if there was some way of lubricating the bearing between the hub and the box, that possibly this would be overcome.

Mr. West said that the use of grease over oil was a matter of cleanliness. I think he is entirely right. In the use of grease we have our enginemen in the roundhouse fill all the cups, eccentrics, front and back ends of main rods, so that the engineer has very little oiling to do on the road. One screwing of the eccentric cup down at the terminal runs the engine 152 miles in freight service and there is no trouble experienced. I think grease is far superior as a lubricant to oil.

MR. M. H. WICKHORST (C. B. & Q.): I want to say another word, showing the principle involved. On the one hand, as I explained, with a very little piece of mechanism, like a watch, with accurate jewel bearings, oil is a detriment, whereas on the other hand, with a high-pressure gauge tester that I sometimes have occasion to use, and where we get a load of 10,000 pounds or 20,000 pounds on the fraction of a square inch, we found that the heaviest oil, mixed with graphite, is not sufficient to keep the surfaces apart, and we used metallic lead. It shows we have to use something of a sufficient viscosity to keep the bearings apart.

The grease ordinarily used for locomotives consists of soap and oil and is not an ideal material for the purpose. Possibly trial would show the heavier mineral or organic oils to be satisfactory and economical, considering the greatly increased machine friction with the ordinary grease.

G. W. WILDIN (Erie): We have now in all about 237 engines with the driving boxes and crank pins equipped for grease lubrication, some of them having been in service about two years, and I might add that I have not as yet had a report of a single hot driving-box on an engine which is equipped with grease cellars. We tried the grease cellars in the trailing boxes of our Atlantic type engines, and were compelled to remove same, as they were an absolute failure. It seems that to use grease as a lubricant, it must be applied to surfaces where there is more or less lost motion in the parts, in order to allow the grease to get between the surfaces; in the case of trailing boxes, there is no jarring motion to separate the surface of the axle from the brass, consequently the grease can not enter, and so far as our experience goes, the results were anything but satisfactory.

We are using for lubricating crank pins what is called a spring compression cup, which does away with the necessity of the engineer screwing down the grease plug at the commencement of each trip. It has been found that we can get much better results with the compression cup than any other device we have tried, so far as good lubrication goes, and at the same time greatly reduce the amount of grease consumed. At present we are getting about 3,000 miles to one filling of a side rod cup, 2,500 miles for a main connecting cup and 1,500 miles for a main rod cup. Since

the introduction of grease as a lubricant, and its use has become more extended, we have materially reduced our cost of lubrication. Some experiments were made on the Erie on one of our Atlantic type engines, before grease as a lubricant was entered into very extensively. The engine left the shop after receiving general repairs, the driving boxes being fitted with grease cellars properly packed. After remaining in service a year, it was again shopped for general repairs and again returned to service with the same grease in the cellars as when it entered the shop. During the past year I have had some figures prepared showing the relative cost of lubricating the driving boxes of an Atlantic type engine with grease as compared with oil. A cost of 2.5 cents per journal per 1,000 miles is incurred where grease is used, as against .31 cents per journal per 1,000 miles, with oil. This would make the cost of lubricating the driving boxes of an Atlantic type engine 10 cents per 1,000 miles with grease, as against 1.32 cents per 1,000 miles with oil.

MR. E. W. PRATT (C. & N.-W.): Does that include the labor of packing, etc?

MR. WILDIN: It included everything.

MR. PRATT: 1.32 cents a thousand miles for the oil?

MR. WILDIN: Yes, for the four driving wheels.

MR. PRATT: And about 10 cents for grease?

MR. WILDIN: Yes.

MR. PRATT: The Chicago & North-Western made some tests that showed a little higher than that for oil, and about 3 cents per 1,000 miles for grease.

As to what Mr. Peck suggested, regarding the wear on pins and brasses, while there is no question in testing a device experimentally you can show the wear is greater with grease than with oil, the wear with the file is much faster than the wear with grease, and when the pins get cut, as they do without grease, on most of the heavy engines, the wear with the file is very excessive, and actual tests we have made on a considerable number of engines — applying grease to the pins on one side of the engine and oil on the other side — shows very much in favor of the grease, from shopping to shopping, as to the wear both on brasses and on pins.

MR. DAVID BROWN (D. L. & W.): We have our engines pretty thoroughly equipped with grease, and we consider that the experimental stage has gone by. We consider grease a necessity for lubricating driving-box brasses and crank pins. A remark has been made about the increased consumption of coal. Probably the use of grease might necessitate the use of a little more coal, as we do not cut down the tonnage any. Professor Goss has shown us that the drawbar pull is but slightly affected by the use of grease instead of oil.

The use of grease eliminates roundhouse work, packing boxes, and does away with the engineer's uneasiness. If he gets a box a little warm, when he is using oil and waste, he has got to take out this oil and waste and repack it, and in the case of the waste some of it is used again and some thrown away. In addition to that there is the labor and delay causing an engine failure and in some cases the giving up of trains. With the grease we hear nothing of that. When the grease is used a box may be run, although it becomes so warm that, if the oil were used, it would be necessary to remove the packing, but with the use of grease, the engineers take no notice of such a warm box, feeling confident that they will make the trip satisfactorily. When they come into the terminal they do not even have to report such a warm box, but if oil were used instead of the grease it would be necessary to report the hot-box and have it repacked.

We certainly are in favor of the use of grease in driving boxes and pins. It gives the best results we have experienced with either form of lubricants.

PROF. W. F. M. GOSS: It would be a mistake to characterize this brief report which has been presented as an argument. It is not an argument; it is a mere presentation of certain facts. Mr. West has asked for some information regarding our success in lubricating with oil. The report itself, on page 4, gives a statement of our experience covering that matter. It was rather a strange fatality that when we had finished our work with grease and attempted to proceed with oil, we at once got a hot box. In explanation of that we discovered that by a mistake, instead of serving the axles with axle oil we had served them with car oil and the car oil was not sufficient to keep the journals cool at high

speed. We had to refit the axles and begin again, and after that we had no trouble whatever in lubricating with oil.

It has been remarked that the tonnage rating has not been reduced. I think that is in accord with the showing in this report, to which I have referred, which is to the effect that under the slow speed of ordinary freight service the loss is not great by the adoption of grease; but the fact remains that there is 1,000 pounds difference, about, in the drawbar stress, required to overcome the machine friction. That is a fact, but we may as well all recognize it, it seems to me.

I agree with the general statements of Mr. Wickhorst. It is a fact, which we always recognize in the use of oil as a lubricant, that it is desirable, from the point of view of reduced friction, to use as limpid a lubricant as possible; yet we are compelled, in order that we may operate successfully, to increase the viscosity of the lubricant up to a point where we may be certain of securing satisfactory action. And here it is not to be regarded as bad judgment, or bad practice, if we insist upon using a lubricant which gives satisfactory operating results, even though it does involve some increased loss by friction, and it is well to know the facts in the matter.

THE PRESIDENT: In connection with the report of the Committee on Locomotive Lubrication, you will notice that a definite recommendation is made in the last paragraph of the report, namely: "Your committee would suggest that the recommendations in part No. 4, Consideration of Standard Fittings, be referred to letter ballot for adoption as standard, and would ask that the committee be continued."

MR. C. A. SELEY (C. R. I. &. P.): I make a motion, that the recommendation in part No. 4 be referred to letter ballot for adoption as a standard, and that the committee be continued. (Carried.)

THE PRESIDENT: The next business in order is the report of the Committee on Specifications for Cast Iron to be used in Cylinders, Cylinder Bushings, Cylinder Heads, Steam Chests, Valve Bushings and Packing Rings. The report will be presented by Mr. G. R. Henderson, chairman of the committee.

MR. HENDERSON presented the report as follows:

REPORT OF COMMITTEE ON SPECIFICATIONS FOR CAST IRON TO BE USED IN CYLINDERS, CYLINDER BUSHINGS, CYLINDER HEADS, STEAM CHESTS, VALVE BUSHINGS AND PACKING RINGS.

To the President and Members of the American Railway Master Mechanics' Association:

In approaching this subject your committee endeavored to obtain information from locomotive builders and steam engine manufacturers, as well as from various railroad authorities, but found comparatively little material by which to be guided. Many of the railroads and manufacturers are contented to purchase pig iron in the old way, by grade numbers and by depending upon the general reputation of the furnace, without endeavoring to learn the chemistry of the iron so purchased, and the mixing and charging are adjusted in a similar way, the parties, however, claiming, generally, satisfactory results. Car wheels were formerly made in the same manner, a 5 per cent charge of Salisbury, with its magic name, being expected to elevate the whole mass to the desired standard; but repeated failures, with disastrous results, compelled a more scientific treatment.

In order to set forth the various stages of cylinder metal production and the reasons therefor, we will group the subject into several subdivisions.

PURCHASING.

It is recommended that all purchases of pig iron be made by analysis. This necessarily implies penalties for non-conformity with specifications, and the amount of silicon is considered to be of prime importance as indicating the grade. High silicon irons — that is, low foundry numbers — are generally dearer than low silicon (high numbered) irons, and if the shipment does not contain the desired percentage of silicon, payment is made accordingly. For example, with some purchasers a deficiency of silicon of from 10 to 20 per cent subjects the shipment to a 4 per cent reduction in the contract price; or, again, at other times the bill is settled as for the grade shown by the silicon contained. Sulphur is the element to be most carefully kept down to the limit and an excess of this substance will generally entail rejection under any grade.

When purchasing cylinders, valves, etc., analyses and test bars should be insisted upon, to demonstrate that the metal is in accordance with the desired specifications.

SPECIFICATIONS.

For coke pig iron, these are usually limited to the chemistry of the metal. The usual proportions are given as follows:

Combined carbon	.40 to .70 per cent.
Manganese	.40 to .80 per cent.
Phosphorus	.40 to .80 per cent.
Sulphur, not over	.06 per cent.

The grades are determined by the amount of silicon, in accordance with the attached schedule:

Grade No. 1, Silicon	3.00 to 2.50 per cent.
Grade No. 2, Silicon	2.50 to 2.00 per cent.
Grade No. 3, Silicon	2.00 to 1.50 per cent.
Grade No. 4, Silicon	1.50 to 1.00 per cent.

The grade desired for cylinders is about No. 3.5, or say, silicon from 1.25 to 1.75 per cent. However, cylinders are seldom if ever cast from one grade of iron only, as there is usually a considerable proportion of scrap, sometimes as much as 50 or 60 per cent. The specifications for iron in the cylinder castings, that is, after the castings themselves have come from the foundry, will be given later on.

INSPECTION.

Various plans are followed for sampling and inspecting pig iron when received in carload lots. The American Society for Testing Materials has adopted the following rules:

SAMPLING.

"In all contracts where pig iron is sold by chemical analysis, each carload, or its equivalent, shall be considered as a unit. At least one pig shall be selected at random for each four tons of every carload, and so as to fairly represent it.

"Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

"In case of disagreement between buyer and seller, an independent analyst, to be mutually agreed upon, shall be engaged to sample and analyze the iron. In this event one pig shall be taken to represent every two tons.

"The cost of this sampling and analysis shall be borne by the buyer if the shipment is proved up to specifications, and by the seller if otherwise."

The Baldwin Locomotive Works state that six pieces of pigs will be taken from different portions of the car, and if the analysis of their mixed drillings shows that the iron is outside of the specified analysis, it will be cause for its rejection.

The American Locomotive Company has prepared a specification in which they state that "Check analysis will be made for each car received

at the foundries, from a mixture of equal amounts of drillings taken from freshly fractured ends of three pigs, one from each end and one from middle of car. If this analysis is not within the specification, drillings will be taken in the same manner from seven additional pigs." In other cases samples of twelve pigs are taken from each car, two from the top of each end, two from the middle and two from the bottom, the borings being mixed in equal quantities and the resultant sample taken to represent the shipment. Almost any of the above methods will be generally satisfactory if closely adhered to.

CHARGING.

In mixing the iron for the cupola it is necessary to know the chemistry of the metals charged and the desired analysis of the output. If the above plans have been followed, we can mix the charges in the proportions needed, allowing for loss in melting. It is not necessary to consider the specific name of the iron used, but its composition is of vital importance, and the various brands must be thoroughly mixed in the cupola. The percentages of the various elements in the casting will be different from that in the average charge. The amount of phosphorus usually remains constant, while silicon diminishes, particularly when more than 1 per cent is present. Part of the manganese is always oxidized—the greater the amount the greater the proportion—and sulphur is likely to be increased by absorption from the fuel. For this ingredient it is more necessary to watch the coke and the working of the cupola than the metals which are charged. The total carbon remains practically unchanged.

From this it will be seen that fifteen or twenty points more silicon must be charged than expected in the casting, and this is really the most important element in the iron, as it determines the hardness of the product in an inverse ratio to its presence, that is, the more silicon the softer the iron. It also affects the strength, giving a maximum tensile resistance at about 1.60 per cent. Phosphorus and manganese act as hardeners and also cause the iron to flow readily and make a clean and sound casting, but if present in large quantities, brittleness is apt to ensue. When sulphur is excessive there is a greater tendency to crack, and it should not be allowed to rise above set limits. This is particularly true for complicated forms, like a locomotive cylinder. Some manufacturers, however, claim that there should be at least .07 per cent sulphur in a cylinder casting to get the best results.

It appears from the foregoing that it is essential to carry on hand a liberal stock of irons of known analyses, so that the desired combination can always be secured.

PRODUCTION.

A locomotive cylinder should combine strength and hardness—the former to prevent breakage, the latter to retard wear; however, it must

not be brittle and must admit of machining. A cylinder may be made of tough iron and a hard bushing inserted to give the wearing qualities. In fact we know of recent cases in which the cylinder shell has been a steel casting, with cast iron bushings inserted in the piston and valve chambers. Shrinkage must also be considered, as when excessive there are apt to be cooling cracks present in the casting.

We present herewith several chemical specifications for cylinder irons, meaning by this the analysis desired in the casting when it leaves the foundry.

CHEMICAL SPECIFICATIONS FOR LOCOMOTIVE CYLINDER IRON.

Authority.	Percentage of					
	Si.	P.	S.	Mn.	C. C.	G. C.
Am. Soc. Test. Materials	1.25—1 75	.90 Max.	.10 Max.	.....	.....	.....
Am. Loco. Co.	1.20—1.40	.90 Max.	.10 Max.	.9 Max.	.....	.....
Bald. Loco. Works	1 30—1.70	.60-.90	.07-.12	.35	.60	.....
N. & W. Ry	1.25—....	.....	.....	.....	.60-.65	.....

There are also specified certain physical properties which are desired. The American Society for Testing Materials, in their specification adopted November 15, 1904, calls for a center test load of 3,000 pounds on a bar 1¼ inches in diameter, placed on supports 12 inches apart, and a deflection of not less than .10 inch. The American Locomotive Company requires a tensile strength of 25,000 pounds per square inch and a transverse load of 3,000 pounds on a bar 1 inch square with supports 12 inches apart. The shrinkage is to be not over .15 inch in 13⅓ inches of length, or ⅛ inch per foot as maximum. The Baldwin Locomotive Works specifies 27,000 to 33,000 pounds per square inch tensile strength. The transverse tests above given correspond to an ultimate fiber stress of 45,000 and 54,000 pounds respectively for the 1¼ inch round and the 1 inch square bars.

We have also the chemistry of some cylinders which have given very good service, and they are stated below:

Road.	Si.	P.	S.	Mn.
N. & W.	1.19	.64	.084	.68
N. & W.	1.49	.64	.092	.38
N. & W.	1.65	.93	.069	.29
Southern	1.21	.36	.059	.30
Southern	1.21	.36	.059	.30

On the other hand, some cylinders that were found to be too soft and very unsatisfactory in service, owing to the fact that they cut very readily, had the following chemistry:

Si.	P.	S.	Mn.	C. C.	G. C.
2.15	.37	.034	.51	.26	3.36
2.15	.43	.035	.58	.27	3.37
1.72	.35	.044	.55	.28	3.31
2.10	.35	.039	.53	.21	3.31

These values are understood, of course, as being in per cents. When the silicon is above 1.80 per cent, excessive wear may be expected, but when below 1.00 per cent there is liability to crack in cooling or in service.

Your committee therefore recommends the following specifications for metal in locomotive cylinders:

Silicon	1.25-1.50 per cent.
Phosphorus	.50- 80 per cent.
Sulphur	.06- .10 per cent.
Manganese	.30- .60 per cent.
Combined Carbon	.50- .70 per cent.
Graphite Carbon	2.75-3.25 per cent.

Tensile strength, 25,000 lbs. per sq. inch min.
Transverse strength 3,000 lbs. minimum on 1¼-inch round bar, 12 inches between supports.
Deflection, .10 inch minimum on transverse test.
Shrinkage, ⅛ inch in 1 foot as a maximum.

TESTING.

The American Society for Testing Materials gives the following details for testing such castings, and your committee recommends them to the Association:

"The quality of the iron going into castings under specification shall be determined by means of the 'arbitration bar.' This is a bar 1¼ inches in diameter and 15 inches long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for it may be made from any of the broken pieces of the transverse test. The expense of the tensile test shall fall on the purchaser.

"(The tensile test piece should be prepared with threaded ends, 1¼ inches in diameter, and with a central neck 0.8 inch diameter, 1 inch between shoulders, with a 7-32 inch radius at the shoulders, the shoulders being 1 inch in diameter and ¼ inch in length to the thread, the total length of piece being about 3½ inches.)

"Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds twenty tons an additional set of two bars shall be cast for each twenty tons or fraction thereof above this amount. In case of a change of mixture during the heat one set of two bars shall also be cast for every mixture other than the regular one. Each set of bars is to go in a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

"The transverse test shall be made on all the bars cast with supports 12 inches apart, load applied at the middle, and deflection at rupture noted.

One bar of every two of each set made must fulfill the requirements to permit acceptance of the castings represented.

"The bars shall be molded two in a flask and cast on end; the bottom of the bar being 1-16 inch smaller in diameter than the top to allow for draft. Pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

"The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 inch.

"Borings from the broken pieces of the arbitration bar shall be used for the chemical determinations. One determination for each mold made shall be required."

Some manufacturers prefer to cast a bar for tensile test with each cylinder in addition to the above bars. In many instances more dependence is placed upon the chemical analysis than the physical tests.

UNIFORMITY.

The presence of scrap and other uncertain elements in the charging causes some irregularity in uniformity of the products, but with careful work satisfactory results can be obtained. At the 1897 meeting Mr. Vauclain showed the results of charging by analysis and in no two of the given cases were the same kinds of iron used. These are here reproduced:

	Tensile.	Combined Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon
1	35,960	.52	.35	.63	.11	1.47
2	30,900	.51	.34	.57	.10	1.62
3	30,130	.51	.33	.75	.10	1.49
4	28,310	.50	.35	.83	.07	1.50
5	31,390	.54	.36	.74	.08	1.41
6	31,800	.60	.32	.65	.10	1.44
7	32,700	.62	.35	.59	.12	1.52
8	30,530	.50	.32	.49	.12	1.35
9	31,110	.63	.34	.59	.12	1.41

Owing to numerous causes a variation of 20 or 30 points is sometimes found in the silicon and perhaps 4 or 5 points in sulphur, due largely to the fuel, but as the former is apt to decrease and the latter to increase, careful charging will produce quite regular results, in spite of the variation between different taps.

RESULTS.

The cylinders made in accordance with the various formulæ or analyses (which are very similar), are reported as having good wearing qualities

combined with strength, and this seems to be the case without regard to the particular brand of iron used, so long as the final analysis of the cylinder is satisfactory. The iron is harder, stronger and closer grained than the ordinary foundry output, but no trouble is experienced in machining with modern tool steels. If the silicon runs much above the limits specified, the cylinders will cut readily, as above demonstrated, or if below 1 per cent, they are subject to cracks. Some manufacturers mix charcoal and coke pig with good wearing results, but it is thought that cracks are more common with this method, as also when using cold blast irons. If sulphur runs high there is trouble in obtaining a perfect casting for such a complicated pattern.

From information gathered, it is evident that many foundries are still charging by fracture and furnace name and number, but as irons are so liable to vary in their analyses, depending upon the working of the furnace and variations in the ore and fuel, it is surprising to your committee that the method of mixing according to analyses has not been more generally adopted, especially as different localities must purchase iron where the haul will not be excessive.

GENERAL.

While the metal advocated is perfectly suitable for cylinder bushings, as well as cylinders (and we also think for valve bushings), a softer grade of iron is generally used for cylinder heads, steam chests, valve bushings and packing rings. This iron has a silicon content of from 1.60 to 1.80 per cent; the other elements remaining about the same. As shown on page 215, Vol. 30 of the Proceedings of this Association, the greatest strength was obtained with silicon at 1.60 per cent, and for cylinder heads and steam chests strength is most important. In packing rings a softer iron is desired to save the cylinder bore, and the strength is also a very important factor to prevent breakage when springing over pistons or from water accumulating in the cylinder.

G. R. HENDERSON, Chairman,
E. D. NELSON,
MAX H. WICKHORST,
Committee.

NEW YORK, May 1, 1906.

THE PRESIDENT: If there is no objection, the paper is before you for discussion.

C. A. SELEY (C. R. I. & P.): Mr. President, I think the committee is to be commended for submitting an amount of information to this Association which will give a specification, although I regret that the committee did not submit a definite

form upon which we could at once take action. I note some differences in the chemical properties as submitted by the committee as compared with the form adopted by the American Society for Testing Materials. The chemical properties of that association show silicon 1.35 to 1.75, whereas our committee recommends 1.25 to 1.50.

The paragraph on page 4 and again on page 8, shows an upper limit for silicon of 1.60 perhaps might be more desirable, and take the chance of cutting referred to on account of the desirability of the other qualities. The Testing Materials specification also takes up phosphorus and sulphur, whereas our committee adds to these manganese and the carbons. I am not enough of a chemist to know whether we can discriminate as closely as that. I think it would be desirable to get a start in this matter, and I would therefore move that this committee be requested to submit a definite form of specification to the Executive Committee, the same to be submitted to letter ballot, with the modification of the silicon reading 1.25 and 1.60.

MR. T. H. CURTIS (L. & N.): Mr. President, the wearing quality of the cylinder can be varied a great deal by the manner in which the cylinder is made. I have experimented considerably in making locomotive cylinders, and believe it to be of advantage to use a dry sand mold and core, which is more expensive to make, but insures a uniform cylinder.

Again, the method of cooling a cylinder makes a large factor in the wearing quality of it. If a cylinder is poured and stripped of the mold as soon as poured, you will have a very hard cylinder, one perhaps so hard that you can not machine it. If you bury the cylinder in the cylinder pit for two or three days and let it cool, you will have a soft cylinder, and I find that by the method of cooling you can vary the hardness of your cylinder. If you want a hard valve seat, when it is cooling strip the valve seat and let it cool quickly, and it will chill to some extent.

THE PRESIDENT: Gentlemen, you have heard the motion made by MR. Seley, that the committee submit to the Executive Committee definite specifications with a modification in the limits for silicon.

MR. C. A. SELEY (C. R. I. & P.): Mr. President, this refers of course to unbushed cylinders, cylinders that can be used directly without bushing.

THE PRESIDENT: To be submitted to letter ballot.

MR. H. H. VAUGHAN (Can. Pac.): Would it not be just as well, Mr. President, for that committee to also submit specification for bushed cylinders that could go in as recommended practice?

THE PRESIDENT: Do you accept that, Mr. Seley?

MR. C. A. SELEY: Yes. (The President then put the question, and it was determined in the affirmative, and upon motion the discussion was closed).

THE PRESIDENT: The next in order is the paper on "Electricity on Steam Railroads."

REPORT OF COMMITTEE ON ELECTRICITY ON STEAM RAILROADS.

To the Members of the Master Mechanics' Association:

(1) The instructions of your Committee on Electricity on Steam Railroads read as follows: The committee to consider and present to the Association the relative advantages of the different systems of electric traction now in use as applied to interurban and suburban lines; also, as far as possible the relative cost of operating such lines by electricity and steam. The committee are also instructed to include in its investigations the different systems of gasoline, gasoline-electric and steam motor cars.

(2) This commission is almost the first recognition in this Association of other motive power than the steam locomotive and your committee doubts its ability to cover the whole ground of its instruction in a perfectly satisfactory and comprehensive manner, for the reason that the factors in each railroad proposition vary from its neighbor even as men vary in their personal characteristics.

(3) We understand that main line operation is not to be considered, but that branch lines, suburban and interurban lines which are feeders to main lines are to be discussed.

(4) We understand, also, that the question relates mainly to passenger traffic on account of the expression "now in use," as electric traction of freight is carried on to a limited extent only at the present time. Mail, baggage and express are being handled, but these are generally considered in connection with or a part of the passenger traffic.

(5) No steam railroad will consider abandoning its freight service in favor of electric passenger service, and we are therefore under the necessity of considering provisions for both classes of service, and for convenience the passenger service will be taken up first.

(6) The class of service we have to consider breaks away from the steam railroad ideas of trains of cars drawn by locomotives, and takes up the individual car or cars, each provided with means of propulsion taking power from some central source.

(7) The main business of railroads is to sell transportation, and the only object in considering electric traction is to ascertain whether the cost of carrying passengers can be decreased or the amount of travel be so increased as to provide additional revenue to the road offering it.

(8) Inasmuch as the proposition in hand is based on the street car idea and methods it might be well to look up the history and development of that branch of traction which began in this country about 1850, the cars being drawn by horses. In 1873, the cable system was introduced and after twenty-five years very few survived, although the cost of their construction was very heavy. The early development of motor-driven electric cars occurred mainly after 1880, and in the year 1890 the census report gives for the United States the following mileage of street and suburban railways:

Electric	1,261.97	miles
Animal	5,661.44	"
Cable	488.31	"
Steam	711.30	"
Total	8,123.02	"

In 1902 the mileage was:

Electric	21,907.59	per cent, increase		1636.
Animal	259.10	"	decrease	95.4
Cable	240.69	"	"	50.7
Steam	169.61	"	"	76.2
Total	22,576.99	"	increase	177.9

(9) Thus it will be seen, that, although there was a very large increase of total mileage in the above twelve years, yet the greater proportion of the increase of electric traction was at the expense of the other methods of traction.

(10) During this period there were some ephemeral experiments in the use of batteries and of stored compressed air for power purposes on cars, but none of these survive.

(11) The above figures show the backward development also of the

steam-driven car or "dummy" for such service, despite the vast advance in steam-railroading proper during these years, and this in itself is almost a complete argument against the steam car or other types of self-propelled car, except for special situations.

(12) In early electric street railway traction several attempts were made to utilize an electric locomotive, but these were generally abandoned, although it is customary now on some roads to have trail cars attached to leading motor cars. The latest and most advanced practice is to have all cars equipped with motors controlled from the leading car. The development in electric cars has been marked not only by their increase in size and carrying capacity but also in the size of motors employed. The earlier cars had 15 or 20 horse-power equipment, but it was soon found that these were inadequate to properly accelerate loaded cars, and now many heavy suburban cars are equipped with four 75 horse-power motors, each, and in some cars the motor equipment totals 400 horse-power.

(13) We have, therefore, available for comparison the steam railroad train, consisting of a locomotive with as many cars as the service demands, running at infrequent intervals, and covering perhaps two hundred miles per day, as against the same road operated with individual electric cars, obtaining power from a general source, running at frequent intervals and fairly equivalent mileage.

(14) It is perfectly apparent that the density of traffic is the ruling factor as to whether the steam or the electric road will prove the more profitable.

(15) It is quite well known on old-established lines what the passenger returns will be with fairly steady business conditions, provided there is no change in the train accommodations, but if there is an increase in train service it is almost sure to build up an induced traffic, the amount of which is difficult to estimate. Unless, therefore, there is a reasonable basis of expectation for such traffic, the steam railway that can fully care for its own is not in need of a new system, and the expediency is doubtful.

(16) On the contrary there are many sections of country, well populated and suburban districts, where an increase of travel may be induced by improved facilities, the amount of which can be gauged by the density of population.

(17) The travel which is contemplated is the local, short runs, which in many cases has been taken from steam railroads by competing electric lines, this proving that the more frequent service and general convenience of the trolley line is more attractive. Absence of smoke and cinders, open cars in season, connections with city lines, all add to the popularity of the trolley and give a business that can be profitably carried at lower rates, which, after all, is the main inducement.

(18) It is believed, therefore, that where there is a sufficient density of traffic it will pay steam railroads to handle their local suburban and interurban travel electrically, giving frequent trains and frequent stops, equaling the convenience and accessibility of trolley lines, for which the public does not have to stop to consult time tables, buy tickets and go to inconvenient points to get on trains. Traffic of this kind should have its separate tracks, as it would get in the way of fast through trains and itself would be impeded by slow freight trains, using the same tracks.

(19) It would be possible to make a combination service in some territories, running slow freight though at certain hours when travel was light, or if the character of the freight would permit, to have special separate freight units which could keep out of the way of passenger traffic. As before stated, the particular class of service and the system to be used must be chosen with special reference to the situation, and these vary so that no general rule or information will apply.

(20) It is our belief, however, that few situations will figure out profitably with the combination service, and that if electrification is warranted for passenger traffic, that a complete change will be desirable, except possibly where there is through travel involved also.

RELATIVE ADVANTAGES OF DIFFERENT SYSTEMS OF ELECTRIC TRACTION NOW IN USE.

(21) By far the greater portion of present car equipments are for the use of direct current, but of late alternating current has entered the field and there are some very interesting single-phase operations, the motors employed being capable of running on either direct or alternating current, and by having suitable transformers on the cars, high line voltage may be carried, thus reducing the cost of distribution.

(22) Long distance distribution is best accomplished by alternating current of high voltage, and if direct-current motor equipments are used the current is transformed at substations at suitable intervals and generally not over ten miles apart. These stations are equipped with transformers for stopping down the voltage, and with rotary convertors for changing the current to direct at suitable voltage for the line.

(23) Substations on lines employing single-phase machinery have only the transformers, no rotaries being required, and this also cuts off cost of attendance except occasional inspection.

(24) The single-phase operation is economical on account of high voltage used on the line and cheapens very much the cost of distribution from the substations, there being no difference between the power station and substations. The car equipments, however, are more expensive than direct-current apparatus, so that, assuming both to be of equal efficiency, the number of equipments and apparatus required must be considered, and

their extra cost weighed as against the low cost of direct-current machinery and more expensive distribution to the line.

(25) The present New York Central—New Haven R. R. situation is an interesting example of the application of these two systems of electric traction, and the ultimate working out of these two great problems will add greatly to the shaping and development of the future of electric traction.

RELATIVE COSTS OF OPERATING BY ELECTRICITY AND STEAM.

(26) The relative costs of operation with electricity and steam are difficult to state as there is very little accurate information of value. The results obtained by attempting to draw comparisons from hypothetical roads would depend entirely upon the assumptions which were made. For instance, a set of conditions could be assumed which would show a much lower cost of operation by electricity than by steam ; another set could be assumed which would show practically equal cost, and a third set which would show that steam operation would be the most economical. In view of the fact that the assumptions would govern the results, it is believed that information of this nature would not be of value to the Association and might lead to erroneous assumptions and misunderstanding.

(27) A number of electrifications are under way at the present time, employing various systems of distribution, and a considerable amount of data will no doubt be available in the near future.

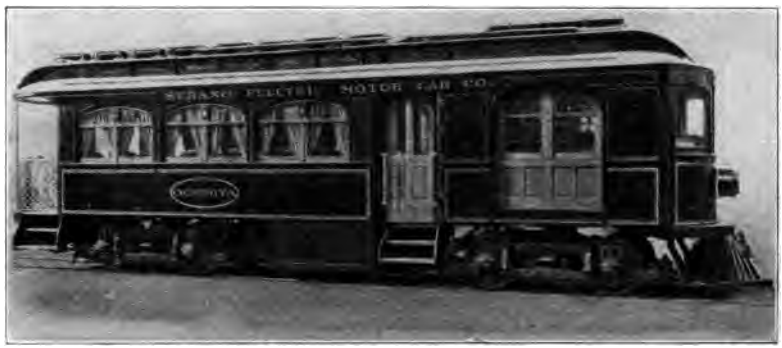
(28) Relative subjects which would be of interest and value to this Association are the character of the shops, shop equipment and apparatus necessary for the maintenance and repair of electric equipment; also the power houses and their equipment.

GASOLINE, GASOLINE-ELECTRIC AND STEAM MOTOR CARS.

(29) Some time prior to the development of electric interurban railways the steam motor car or dummy, in many cases hauling a trailer, was used to a moderate extent, but at the present time few of these remain. In response to a demand from railroad managers for a motor car to operate on branch lines and special situations there has been recently a development of motor cars employing gasoline in an internal combustion engine, this engine either directly driving the car or driving a dynamo to generate current to be used for driving motors in the trucks. Some builders interpose batteries between generator and motors to store the current when it is not all needed for propulsion, and to assist in starting on grades when the generator capacity may be insufficient. There is very great flexibility and convenience in this combination, but it is attained at very considerable expense and complication, and requires unusually skilled attendance not commonly available in railroad service.

(30) The examples of the gasoline engine, electric generator, battery and motor types are the cars of the St. Joseph Valley Traction Company's

line, built by F. M. Hicks, and the Strang car that lately made a successful run from New York to Kansas City. The gasoline engine on these types is set to run at a constant speed, and this characteristic is essential for the best economy of the internal combustion engine. The size of the engine used may be proportioned to the average power required for normal operation, and the speed variation and excess of power above normal requirements may be supplied by the battery equipment, which also comes into play for lighting and short movements and would also be available to bring the car in in case of a breakdown of the engine or generator.



(31) The gasoline-electric type not employing batteries is illustrated by the D. & H. car recently built by the General Electric Company. The generator on this type of car has to be equal to the maximum requirements, and in order to vary the current for the conditions to be met, the field excitation is handled by a separate exciter, chain-driven from the main generator. The controller is semi-automatic and can be set for any predetermined maximum acceleration, and the speed of the car is governed by varying the field strength of the generator. The speed of the engine remains constant after acceleration. This application is very ingenious and effective, and we understand that the car has been put into regular service between Schenectady and Saratoga.

(32) The Union Pacific motor car, representing the direct mechanical drive application of gasoline power, is driven by a six-cylinder reversible gasoline engine, with crank shaft at right angles to the length of car; a sprocket mounted on same, driving a special chain, transmits the power direct to the driving axle through a second sprocket attached to the axle. The chain easily shows a transmission of power with an efficiency of ninety-seven per cent, which clearly demonstrates that this method of transmission is very close to the maximum efficiency possible.

(33) For the initial start of car, or putting it in motion, a reducing gear is used, and, until the car attains a speed of six or seven miles per

hour the economy of this transmission is somewhat reduced; but, as the use of the gears is only temporary and lasts only a few seconds, it can almost be left out of consideration.

(34) The roof of the Union Pacific motor cars is 24 inches lower than the standard height of coach roof. The car being built of steel, with pointed end and smooth exterior surface, the wind resistance is materially reduced, enabling 100 horse-power gasoline engine to drive car at the rate of sixty-five to seventy miles an hour.

(35) The car framing is a combination of steel shapes and braces, the whole tied together by steel plates, making a unit structure, each part supporting the adjacent ones and bearing its proportion of the burden imposed upon it. These cars weigh, motor and all, twenty-six tons, which of course is a very material factor in the high speed attained by cars in service, and affords considerable economy in comparison with the heavier steam motor cars, some of which weigh seventy-five tons and over, with the same seating capacity. Motor car No. 7 has seating capacity for seventy-five people, and has, in actual service, carried ninety-five.

(36) One of the most important features in the development of the steel motor car is the reduction in height of car and consequential reduction in weight and decreased wind resistance, a result of which is the system

of ventilation — taking fresh air from the front of car, delivering it at floor level and by suction, drawing the foul air out of the roof.

(37) Motor car No. 7 is equipped with metal round sash windows — a window impervious to cold air, dust or water; in fact, is tight as a port-hole on an ocean-going vessel. These windows have demonstrated themselves to be a great luxury to the traveler. The enclosed inside steps, with side door entrance, have also proven very popular with the traveling public. This side door entrance is permissible with steel car construction without weakening same, the side sill being depressed and divided, a portion being carried over the door and the other portion under, all being tied rigidly in combination with the plate and steel sheathing of the car; forming a structure of such strength as to eliminate the usual weakness caused by a side aperture the size of door-opening in these cars.

(38) The first cars—55 feet in length, seating capacity seventy-five and with an engine of 100 horse-power—are particularly adapted for branch line service, where the traffic is insufficient to support a steam service or anything like electric service.

(39) Interest in the steam car is also being revived, as, for example, the Ganz cars imported from Budapest by the Florida East Coast Rys.; also the Erie R. R. and the C. P. R. R. are experimenting with a steam car equipped with a Scotch marine type of boiler, using a superheater and oil fuel. It is believed that some one may undertake to make a so-called flash boiler that will be applicable to this service.

SERVICE AND UTILITY OF MOTOR CARS.

(40) It is recognized that the so-called motor car, one carrying its own motive power plant, whether gasoline, gasoline-electric or steam, occupies a distinct field of usefulness. Many branch lines, now existing, where travel is light, and on new extensions into unsettled country where the business will not return a profit on steam train service, it would have to be run at a loss until a sufficient business was induced or built up by the travel facilities afforded. These situations are the distinct field of the motor car, which can be operated for less per car-mile than by regular steam train or electric methods until the volume of business will warrant the regular transportation methods.

(41) The use of motor cars on the Union Pacific in picking up passengers on branch lines and in delivering passengers at connecting points for through trains, the service of these motor cars is exceedingly lucrative. The matter of giving the branch line patrons of any steam road increased service, with more frequent trips per diem, is very much appreciated by the local community, and their good will is beneficial.

(42) On the hypothesis of the same density of traffic, with the same class of service as would be encountered on one of the ordinary branch

lines of the territory west of the Missouri River, the cost per mile for local train service, equipment consisting of two cars and a locomotive, would be about 24 cents, including repairs, fuel, oil, labor, cleaning, etc.; this for passenger, as well as baggage, mail and express service.

(43) Electric service equipment, consisting of one car and trailer, figuring that the density of traffic is sufficiently regular to support same seven days in a week, is estimated at about 18 cents a mile.

(44) The gasoline service (mechanical-drive only considered), consisting of one car and trailer, with baggage, mail and express service, would cost 15 cents per mile. The latter, of course, would be independent of whether service was six days or seven days per week, the cost simply depending upon the service rendered.

(45) Railroads, therefore, have a choice of the various systems proposed, and a study of the conditions to be met and facilities afforded, both in the way of care and maintenance, as well as the train service proposed, will give the elements by which each situation will have to be studied. The Motive Power Departments will be called upon to participate more and more in advising as to these questions, and in order to be qualified to undertake such work it is very desirable to introduce information and discussion of these subjects in this Association.

C. A. SELEY, Chairman,
W. R. M'KEEN, JR.,
L. R. POMEROY,
C. F. STREET,
F. J. COLE,
Committee.

CHICAGO, ILL., May 11, 1906.

THE PRESIDENT: Gentlemen, the report is before you for discussion.

MR. G. R. HENDERSON: Mr. President, I am very glad, and I think we should all be glad, that this subject is now before the Association. As the committee states, I hope there will be a great deal heard of it. I think the committee is to be congratulated particularly on paragraph 26, in which it states that the relative cost of operation as between electric and steam locomotives depends so much upon local conditions that it would be impracticable to draw any hard and fast rules, and on paragraph 14, where it states that the whole question is one of density of traffic.

About a year ago, in the New York Railroad Club, Mr. Wilgus, of the New York Central, made some very interesting

remarks on the cost of operating roads electrically as compared with steam. He made it very clear at that time that the New York Central had no idea of entering the field with the hope of reducing the cost of operation, and he stated incidentally that the additional costs were about three times the amount of the actual electrification cost. That is, when you considered the arrangement of terminals and the various facilities which they needed to get the full benefit and full advantage of electric traction, those additional costs were about three times the cost of actually equipping the track and getting the trains moving by electricity. I think that is one phase of the problem which probably has not always been studied and considered as carefully as it should be. I think the remarks of Mr. Wilgus, which can be found in the proceedings of the New York Railroad Club, will be of great interest to any one who wishes to look up this subject.

MR. W. R. MCKEEN, JR. (Union Pacific): I do not know, Mr. President, that I can add anything to the report on this subject, except to say that if you take a gasoline motor car and run it on a steam railroad, it is necessary to build the car susceptible to a shock like that of a collision with a locomotive or a strongly built railroad car. This necessarily makes the car much heavier unless you use a steel form of construction. I do not think it would be safe to run the ordinary electric car on a steam railroad. In developing the gasoline motor car we endeavored to put out a car that would be absolutely safe for the traveling public. That adds necessarily to the expense as to first cost. The gasoline cars of the present day are built principally for branch lines, to establish economical service in sparsely populated territory, with the same frequency of service as in a thickly populated territory, which you can do on a low cost of operation. When you come to a city proposition, where traffic is heavy, you would have to use a heavy horse-power car, but on branch lines and in sparsely settled districts a 100 horse-power gasoline engine gives some very remarkable results in operation — that is, you can attain a very high speed at a very low cost and a very low development of horse-power.

THE PRESIDENT: Mr. McKeen, what has been your experience with regard to cost of operation on the ton-mile basis, as com-

pared with the steam locomotive, in the hauling of passenger trains?

MR. W. R. MCKEEN, JR.: It is very difficult, Mr. President, to get at the exact cost of operating the cars on account of the varied service they are giving. So far as the ton-miles go, you can not get at that at all. We can only get at it on a mileage basis. The cost is dependent largely on the method of operation — that is, the number of miles the cars are going per day and what you pay your motorman and crew. If you go into railroad operation and insist upon a conductor and a regular scale of wages, the handling of train orders, etc., it is going to add to the cost necessarily. If you follow out street-car practice, having a motorman and conductor operating one car, with a lower rate of wages, it runs the cost down. Personally, I think that is the only way to operate a motor car, because there is only one car to look after, where the traffic for a good many years will be very limited, but I think 14 or 15 cents a mile could be easily obtained in any ordinary service, where the car makes one hundred or more miles per day.

C. F. STREET (Westinghouse E. & M. Co.): Mr. President, in regard to what Mr. Henderson has just said as to the remarks of Mr. Wilgus at the New York Railroad Club, I think it is quite important to bear in mind the fact that Mr. Wilgus's remarks related purely to heavy suburban propositions. In considering the electrifying of branch lines, the incidental expenses connected with the other things which come in would be no greater with electricity than with steam. The features to which Mr. Wilgus referred were the elimination of grade crossings and other questions which were incident to features of that nature. With regard to the reduction of the cost of operation, it seems to me that paragraphs 42, 43 and 44 outline to a certain extent the fields of the motor car and the electric proposition. The average cost of operation for all of the electric lines of the United States is given at 12½ cents per car mile. The cost of operation per car mile varies all the way from 9.51 per car mile, on the Interborough Rapid Transit in New York, up to as high as 20 and 22 cents per car mile. On the South Side Elevated in Chicago they are operating for 10.50

cents per car mile; Metropolitan, 10.2; Lake Street Elevated, 10.2. I have a considerable list here, running from the Interborough, at 9½, which I believe is the lowest, all the way up to 20 cents. Now, all other things being equal, it seems to me that the question hinges right on that feature of operation. There is a traffic being operated by electric lines running up as high as 20 and 22 cents. All other things being equal, and providing a service which will be satisfactory can be given by the motor car, there is no question but that lines which are running through such operation as this are motor car propositions, and it seems that there is a great field for the motor car.

Then, another feature, with regard to this question of cost of operation — I ran across some very interesting figures after this report was in print. On one of the heaviest elevated railroads of the United States they are running motor cars 65,000 miles between heavy repairs. At the end of a 65,000-mile run the cars are taken into the shop and given a general overhauling, and the average cost of repairs per motor, at the end of 65,000 car miles run, is between $2 and $3 per motor. That is the heaviest cost of the repairs to electric equipment. The repairs for light controllers and light repairs are made on 800 cars by a force of four men. The cars are inspected at the end of every 1,000 miles run. The average number of light repairs made at each inspection on 800 motor cars is from two to three per day. This gives you some idea of the cost of inspection and of heavy repairs to heavy electric equipment. The motors referred to are all of 200 horsepower capacity.

MR. F. M. WHYTE (N. Y. C.): I would like to ask Mr. Street what he covers by the word "motor"; how much of the motor equipment?

MR. C. F. STREET: The entire motor, the armature and fields.

MR. WHYTE: Not the gears?

MR. STREET: Not the gears and pinions. That does not cover gears and pinions. The work usually performed on the motor was merely wiping it off, turning down the commutator and taking the mica from between the bars. Those were the heavy repairs. The heavy repairs to the field, unless there is some breakdown, is nothing.

MR. H. H. VAUGHAN (Can. Pac.): I feel that the portion of this report relating to the electrical equipment of railroads is so complete and its conclusions are so evidently correct that very little discussion is possible on it. A discussion on the relative cost of operation by steam and electricity is not a very profitable one at present. We can reason out what it is going to be and arrive at any conclusion you want to almost, by accepting the premises of different people. But when we come to motor cars we touch a subject that is a pretty live one at present. We were asked, or at least I was asked, to get up a motor car last year experimentally, as most of us are considering it, for branch line service. We were asked to get up a car to be operated by two men. I think a car that is operated by two men is impracticable, except on branch lines, where you are absolutely sure that only one car will be permitted on the branch line at a time. A third man is absolutely necessary for flagging, and now, as the difference in cost between firemen and brakemen is very small, you might as well have a fireman on the car as a brakeman. However, as the result of the demand for a car to be operated by two men, we sent out a steam car operated by fuel oil or with fuel oil as fuel. We have had that car in service about a month now. I might say we looked at the subject of car strength the same as Mr. McKeen has. That was, it would not do to build a very light car for steam line service. We never know when a freight is going to push into the car or something happen. We did not wish to have it said that it was owing to the fact that we put a very light car on, or it would not have gone through.

The car without the motor equipment would weigh about 90,000 to 92,000 pounds, a four-wheel truck car. The water carried adds 9,000 pounds to that, and the motor 30,000 pounds, making the total weight of the car about 130,000 pounds. Our boiler is the modified Scotch boiler, with a superheater and combustion chamber, or intermediate chamber, and circular furnace. One interesting feature is that we have found that on this small car with about a 200 horse-power engine, the results obtained in locomotive practice on large boilers and large engines can be duplicated in every respect. The inches of draft per pound of back pressure are duplicated. The evaporation per square foot

of heating surface is duplicated. The horse-power the car will develop is practically the same; the weight of the boiler per square foot of heating surface is rather less than in the ordinary locomotive. So we really have a reduced locomotive in every way running on that car, and our experience will show that it is perfectly safe to apply existing locomotive data to very small cars of that kind, and expect the results to be duplicated. I might say that the Master Mechanics' improved form of stack can not be duplicated. The stack has to be a little larger than the formula gives. I suppose that is because the size of the front end would be 24 inches, and there is not enough room for the gases in the size the formula gives. After a certain amount of experiments we put the car in service, and the only troubles we have had are, the first trip the car broke a spring hanger and the second time a crosshead arm actuating the Walschaert valve gear. That was due to defective design, but otherwise the cars run pretty satisfactorily. We are making four round trips a day, 23 miles each way. Our regular local passenger schedule, 23 miles, is 50 minutes. We have made it in 38 with the motor car. There is no difficulty in running at a speed of 50 to 55 miles to the hour. I am practically sure we will not go to oil fuel again. We will keep to coal. Coal fuel with us is the cheapest we can get, for the amount of heat it develops. This motor car proposition is one of getting down to the cheapest fuel and everything as cheap as you can to reduce the cost per mile. Where oil is cheaper and the coal more expensive, of course the conditions will be reversed. We have automatic attachments on the car by which, when a man shuts off his throttle he at the same time shuts off a portion of the oil, so he regulates the supply and it does not form a very large amount of smoke. He simply has the lever in front of him and he turns on more or less oil, and with proper draft it is possible to maintain the steam pressure very satisfactorily. The cost of operation is somewhere between 15 and 20 cents. It depends on what arrangements you have with the engineers and firemen. That is, of course, going to be one of the keynotes of this motor car question. In many ways the motor car, it seems to me, is more or less necessary to be attractive to the public. If we were to put on a very small, old-type engine and old car, we could

probably run a cheaper service than we can with the motor service, but the motor car is, I think, an attractive affair to the public; it runs quickly, and with a nicely fitted modern car it forms a very attractive branch-line service. The question in my mind is whether it will pay to put the motor in the car or use a separate motor. I think a separate motor will probably be designed, attractive in appearance, to enable us to put the motor in the roundhouse at night and the car in the yard. That is one of the objections to the combined car. Another objection is the difficulty of washing out; a little boiler like that has to be washed out properly just as a big boiler; it is going to take a certain amount of lining on the inside of the car and so on to keep from spoiling the construction. One of the advantages about the steam car is the fact that you can put that car on a branch line and you have no difficulty with men trained as engineers. The roundhouse force is accustomed to it and there is nothing about the car that involves a new proposition or a new force, and the fuel is, of course, very cheap. With a car weighing 60 tons I think our oil consumption is 1.8 gallons per car mile. You can figure out what the cost per mile is for fuel from that. [Applause.]

THE PRESIDENT: Is there any further discussion? If not, a motion to close the discussion will be in order.

MR. G. W. WILDIN (Erie): I would like to know what Mr. Vaughan pays per gallon for oil.

MR. H. H. VAUGHAN: It depends on what you have to pay for it. We have a special contract for oil. [Laughter and applause.]

(Motion made, seconded and carried to close the discussion.)

THE PRESIDENT: The Secretary has a few notes to read.

THE SECRETARY: It will probably be interesting to the members to hear about the run made to Philadelphia yesterday by the Reading engine. The train was hauled by Engine No. 343, one of the new Atlantic type locomotives designed and built by Mr. Taylor of the Reading Road. Six cars were hauled, three eight-wheel day coaches and three twelve-wheel Pullmans. The weight of the cars was about 246 tons.

The 55½ miles from Atlantic City to Camden were run in exactly 45 minutes, which represents an average speed of 74 miles per hour, for each mile. On the return journey, with the same engine and train, the 55½ miles were run in 43 minutes and 25 seconds, which gives an average speed of 76.7 miles per hour for each mile. Taking out the first 1½ miles from Camden, and the last mile into Atlantic City, the remaining 53 miles were run at an average speed of 44.15 seconds for each mile, or 81.54 miles per hour. From mile post 29 down to mile post 7 these 22 consecutive miles were each made in 40.33 seconds, or at a speed of 89.46 miles per hour.

The fastest mile was run in 38 seconds, or at a speed of 97.4 miles per hour. On both runs Mr. Taylor had issued orders that the train time should not be more than 50 minutes and not less than 45 minutes.

THE PRESIDENT: The next in order is an individual paper on "The Best Method of Welding and Repairing Locomotive Frames without Taking Down or Removing from Engine," to be opened by Mr. R. P. C. Sanderson. As Mr. Sanderson is not here, the report will be read by title only and appear in the Report of the Proceedings.

WELDING LOCOMOTIVE FRAMES.

BY R. P. C. SANDERSON

To the President and Members of the Master Mechanics' Association:

If the bed plate of a 1,000 H.-P. marine or stationary engine broke in two the man in charge would probably feel that he was hopelessly out of business for a considerable time.

The frame of a locomotive fulfils the most important functions that the marine or stationary engine frame performs and has a good many absolutely noncomputable strains to endure that engines on foundations are never subjected to.

The designs of locomotive frames have been brought to their present forms by a long series of remedies for developed weaknesses and stiffening up where breaks have occurred too frequently, often without any clear understanding on the part of the draftsman as to how and why the break was caused.

The locomotives built during this process of development of a type or heavier class of a type are frequently subject to breakages of frames at unexpected places, and although we strengthen the next lot at the weak

place, the locomotives already built remain to plague us by breaking their frames at inopportune times, until the last one of the lot has been strengthened or altered.

There is no more disheartening or exasperating thing in locomotive maintenance than the broken frame. To take the frame down to weld it means dismantling the engine, as nearly everything is fastened to the frame, the foundation of the engine—and with the powerful locomotives of to-day this calls for a tremendous lot of work in driving out bolts, rereaming and refitting.

The ingenuity displayed a generation ago in patching broken frames was great, but with the heavy locomotives and small clearances of to-day patching is not as practicable as it was, and patches we find to our sorrow do not stand.

The first successful attempts to weld broken frames in place, that were given much publicity, were made on the Southern Pacific in California, following which the writer took up the idea and made many successful welds, using kerosene oil as fuel; gas can also be used very well. Each fracture requires its own detailed treatment; there can not be any text-book examples laid down for others to follow. A break in a pedestal leg at the bottom, at the middle, near the top; in the upper or lower bar of the frame; over the driving box; through a bolt hole; at the splice; horizontally, vertically, on a slant — each and every case requires its special treatment.

There are, however, governing conditions that rule in every case that should be understood.

To get a welding heat quickly with the least possible wasting away or burning of the metal, the oil or gas flame must be regulated so that there is not quite enough air to give absolutely perfect combustion, to the end that there will be little or no free oxygen in the flame to oxidize the metal.

For the same reason the little furnace that must be built up and around the fracture to be welded should have only just space enough for the flame to whirl around the frame, give off its heat to the fire bricks and fire clay, which soak it up like a sponge soaks up water, without this flame being driven too hard against the metal, as this will cause wasting away. The inlet for the flame and its first contact with the metal should be at the back or unimportant part of the frame and not against a finished surface, that has been or must be machined, as the wasting away is greatest at first impact of the flame. There should be as little space between the metal to be heated and the furnace wall as will suffice, as the heating is done principally by the heat that has been soaked up by the bricks and is radiated back against the metal. Radiation loses force rapidly with increasing distance.

The outlet for the waste flame should be located where the man doing the job can watch the heat through it and see the weld, as a minute's extra heating is very wasteful.

No more of the frame should be heated than must be to get a good weld, seldom over 4 or 5 inches each side of the weld.

The furnace must be so built that a couple of quick blows of a sledge will knock it all down, clear out of the way, so that the smiths can sledge up the weld on the sides while yet at the serviceable heat. The pit can be partly full of water into which the red hot bricks fall.

A 4 by 5 inch frame can be brought to a welding heat in not to exceed twenty minutes, if the points just mentioned are thoughtfully observed.

When a weld is made in this manner the frame will of course be a trifle shorter and somewhat wasted away, which is objectionable. To avoid this it is best to jack the fracture apart and place between it ⅜ inch of good high-grade soft hammered iron, the irregularity of the fracture will usually keep the surface more or less apart, which has the advantage of allowing the heat to penetrate between the broken surfaces. The soft iron between the broken parts heats first and acts as a cement, welding more easily on the broken surfaces than they will to one another.

To get a perfect weld, a thirty-ton hydraulic jack should be in place before the heat is started, so that when the metal is at welding heat it can be pumped up and force the broken surfaces together at its full power. To prevent the frame bending under this pressure it must be counterbraced, which is usually easy to do. By jacking the fracture together in welding, the surface around the weld is bulged out a little all around and after the furnace is knocked down while the pressure of the jack is still on, the two smiths can hammer away at the surfaces of the weld, leaving enough to chip or file down to a fair bearing for shoes or wedges, etc.

It is best to make some centerpunch marks in the frame well away from the weld on either side; have a tram made to fit these punch marks, allowing just a little for shrinkage for the final cooling off. These punch marks must be well outside of the furnace and the tram made to straddle it, then the tram can be held to place where the jacking is done and the foreman can see when the weld has been sufficiently crushed together.

With skill and thought many a broken frame can be welded in place in this manner and give satisfactory service afterwards, but, if the frame is too weak in design at the broken place, it needs strengthening or it will break again. We can not add metal by welding as described but must resort to some other method.

Here is where the recently invented and developed process of Thermit welding comes to our assistance and this permits repairs to be made and reinforcement to be made on broken frames in cases that could not be handled in any other known way.

The Thermit process is not a welding process in any sense of the word, but is a foundry process — casting process. The blacksmith has little or nothing to do with it; as a general proposition he should be kept out of it, as his life's training, his prejudices and his interests must naturally be in an entirely different direction.

Perhaps a history of the writer's experiences in learning to use Thermit

successfully will serve as a guide for others who have not tried it, or show those who have had ill success with it how they can reach success.

Profiting by the experience of a disappointed neighbor, we did not make any attempt to weld engine frames at first.

The first thing done was to make a few small casts of Thermit; study its temperature and action on small sections of iron and steel.

Following this we took some short broken sections of old frames and laid them in a mold on the foundry floor and attempted to mend the fractures by Thermit.

This process is really a burning-on process, but as it is now always called welding, we will use the usual name.

Following the usual prescription given us at that time by the manufacturers, the first cast was made and the result appeared to be a first-class job; however, bearing in mind the trouble our neighbors had had, the piece of metal was taken and put in a planer and sliced from end to end, exposing the core or center of the weld. One-half of this was polished on the emery wheel on the guide grinder, and this showed — while bright — that the molten steel from the Thermit had welded itself on to the partly fused stub ends of the old frame, but in cooling off had shrunk by natural contraction, leaving a number of cavities, like blow holes, in the center, which very materially weakened the section at that point.

It was found that this metal was exceedingly hard and brittle, while the rest of the frame was of the usual soft hammered wrought iron, consequently we had a hard, brittle, spongy knot in the middle of the bar of soft iron.

The other half of this sample was heated in the furnace and drawn out under the steam hammer. It drew down to about one-half of the original section and then broke in two, right through the old fracture and through the center of the Thermit. The fracture showed that the break had occurred through these shrinkage cavities or blow holes.

Study of the proposition indicated clearly that some method of forcing the broken fracture together, after the cast had been made, and during the process of cooling off, and while the metal was still at welding temperature, was necessary, to close up the spongy holes — in other words the shrinkage must be followed up in order to get solid metal. Another advantage of this would be that instead of the particles of the molten steel cooling off in the form they assume in a steel casting — in other words, in a crystallized condition — that this crushing together would in a measure produce a similar result to a subsequent forging process, in that it would knead or squeeze the congealing metal and make it more ductile.

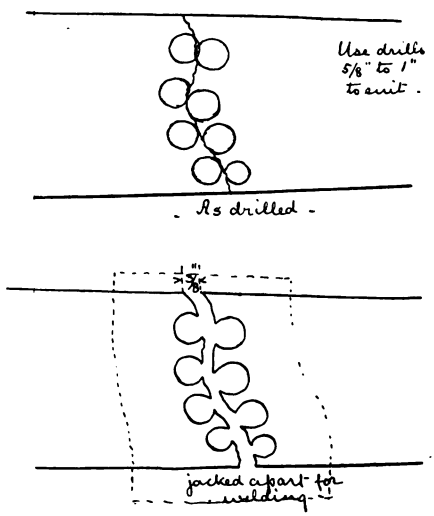
To prove the correctness of this reasoning, a fresh sample was prepared and fresh cast was made with it in precisely similar manner to the first cast, but after pouring the cast the two ends of the frame were forced together with jacks a distance of a little over $\frac{1}{8}$ of an inch.

The result justified our belief. The cavities were very much fewer and much smaller, and crushed together, so that they represented flaws or lines

rather than holes. It was evident that the crushing together process had not been undertaken soon enough, or with sufficient pressure to properly weld up these shrinkage cavities. It was also noticeable on the fractures, after polishing, that there was rather a definite line of demarcation at the junction where the cast steel had burned on to the wrought iron, and in cutting it, it was noticed that when the tool went through the soft iron and came up against the hard Thermit there was a distinctly different resistance, indicating still a hard knot in the middle of the soft frame.

The other half of this section, after being sliced, was drawn out under the steam hammer at a higher temperature than the first cast, and drew down to less than one-third of the original section before fracture took place, and this again showed breakage through the shrinkage cracks or cavities.

Fig. 1



It was evident that our processes were not right yet, and since Thermit steel by its own nature must necessarily be a more dense and harder metal than any wrought-iron or cast-steel frame could usually be, it becomes necessary to figure out some way in which the line of demarcation between the Thermit, which is manganese steel, and the wrought iron, forged or cast-steel frame could be obliterated and be made more gradual, otherwise cracks would be sure to finally come in these frames at the point where this sudden change of quality in the material existed.

After much thought we decided to drill the ends of the frames at the fractures as indicated in Fig. 1, choosing the size of the drills used to suit

the size of the section; thus, as it were, making a series of dovetails in the two ends of the fractured frame, into which the liquid Thermit could be poured and interlock even though the welding might not be perfect. It would also do away with the sharp distinction between the Thermit steel and the soft metal of the original frame.

A third sample was prepared along these lines, and in view of the necessity of forcing it together more than was previously done, the original fractures were separated by small pieces of soft iron about 3/8 inch. The cast was made, and as quickly after the heat and flame and burning slag would permit the sections were jacked together until they resumed the original length between previously located center marks, which meant that the Thermit metal had been compressed 3/8 of an inch after pouring.

This weld showed a very distinct advance over the others. The cuff around the weld was swelled out, due to the jacking process.

When this sample was examined it showed at the section that the junction between the Thermit steel and the original metal was less clearly defined; there were only a few small spots or specks which would indicate shrinkage cavities.

The other half of this section drew down to about one-fourth size without any fracture, except a few small ragged surface cracks at the corners, and we felt that we had succeeded in developing a process which we could rely on to give satisfactory results.

One thing which was noticeable at once in the last experiment, which we had not thought of before, was shown by the polished fracture: the Thermit had melted off the ends of the dovetails, shown in Fig. 1. The conclusion to be drawn from this was obvious: that with such an arrangement as high a temperature as we had been experimenting with, with pure Thermit, was not necessary, and if anything objectionable, so that we added to the following test a proportion of boiler punchings in the Thermit, thus cheapening the process, and as the intense temperature of the melted Thermit was partly used in melting this additional quantity of steel punchings the result was the temperature of the molten metal was reduced; the character of the Thermit metal after cooling off was different, in that it had not been so suddenly chilled and was less brittle, which was an additional advantage gained by this new method.

Feeling confident of practical success we then proceeded to weld broken frames, following the lines of these last experiments, and have been, with two exceptions, universally successful.

To help toward certainty in the weld we arranged the Thermit mold around the fracture with an opening in the bottom for a gas or oil flame and, just as if we were going to make a flame weld in place, the frame and inside of the mold were heated until brought up to a bright cherry red, after which the hole in the bottom of the mold was quickly closed and made secure with a dry sand plug luted in and backed with sand and the Thermit touched off.

By doing this the Thermit was not chilled by a mass of cold frame; it

did not require to be robbed of so much of its heat to fuse the heavy frame ends and a larger proportion of punchings could be used successfully, thus greatly cheapening the work. This preheating of the mold is of great importance.

To reinforce a weak place the usual cuff that is cast around the weld can be extended or thickened, making the weak place stronger than before the break.

There are of course plenty of places about locomotive frames where fractures may occur where Thermit can not be used, on account of the cuff interfering with attachments, but in many such cases we have chipped off such portion of the cuff as interfered and left the balance of it go, in other cases the presence of the boiler mud-ring or other parts up against the frame prevented the use of Thermit. Of course Thermit can not be successfully used at the frame splices and in a few other places, and where it is just as easy to make an ordinary weld by means of a small furnace built around the frame as it is to use Thermit the ordinary weld is preferable and cheaper.

If the information given will help one Master Mechanic to successfully weld even one broken frame in place the time occupied in presenting it to your Association will be justified.

THE PRESIDENT: The next in order is an individual paper on "Fire Kindling; Cost of Material, Labor and Time Kindling Fires in Locomotives, Using Either Anthracite or Bituminous Coal," to be opened by Mr. P. Maher. Is Mr. Maher in the room? If not, the discussion of this paper will be dispensed with, but the paper will appear in the Proceedings. The paper is as follows:

FIRE KINDLING.

BY MR. P. MAHER, S. M. P., T. ST. L. & W. RY.

To the Members:

In considering the subject of Fire Kindling, I find the subject of such varying conditions that to submit a report of any value to the Association, much time and attention would have to be devoted to the subject and I am sorry to say I was unable to devote the time or give the required attention. I am inclined to think the question could be handled more intelligently through a committee than by an individual paper. My recommendations would be to carry the subject over another year and place same in the hands of a committee of at least five members representing roads that use anthracite and bituminous coal, also representation from some of the Western roads using fuel oil. When we take into consideration some of the important features that govern a subject of

this kind, i. e., the antiquated roundhouse with no facilities, the more modern roundhouse, equipped with hot water system and maximum air and steam pressure for blowing up locomotives, the improved smokejack, the various kinds of fuel, etc., we can readily appreciate the fact it could be handled more intelligently by a committee than by an individual. The subject is important and I hope my recommendations will be adopted.

We have an individual paper on "Superheated Steam on American Locomotives," by Mr. F. J. Cole, which does not appear on the program. It was inadvertently omitted. Is Mr. Cole in the room. If not, the paper will appear in the Proceedings as printed. The paper is as follows:

SUPERHEATED STEAM ON AMERICAN LOCOMOTIVES.

BY MR. F. J. COLE.

To the Members:

The theory of the superheater has been presented by Mr. H. H. Vaughan, in his paper before this Association last year. The general subject of superheating, as applied to locomotives, was admirably presented by Dr. W. F. M. Goss before the Franklin Institute in February, 1905, and published in the September journal of that body. In his paper on "Superheated Steam on the Canadian Pacific Railway," presented before the New York Railroad Club in April, 1906, Mr. H. H. Vaughan recorded the results of service experience with a very large number of superheaters on that road. No attempt will be made here to go over the ground so well covered by others.

At the present time it can be asserted confidently that the application of the superheater to American locomotives has come to stay. A sufficient time has now elapsed since its more extended application, which has taken place in the last three or four years, to justify this assertion. The locomotives so equipped have been distributed over a sufficiently wide area to include, generally, all sorts and conditions of service, so that the various kinds of fuel, water, local conditions, etc., necessary to consider in the successful working of locomotives, have been included in these trials.

While some discouraging conditions, such as the accumulation of iron slag on the outside ends of the superheater tubes, caused apparently by an excess of iron in certain grades of coal, have been met with in two or three instances, yet on the whole the consensus of opinion from various railroads confirms the statement that superheating, as applied to locomotive engines, is correct in principle and theory. The economies obtained in fuel and water are considerable, and superheating, generally, may be considered as a

substantial improvement in the operation of locomotives under American conditions.

Following the practice abroad, force feed lubrication was at first considered necessary, and the principal makes of these lubricators, both foreign and domestic, were used in order to determine which kind was best adapted for the purpose. Experience has shown that the usual type of sight feed lubricators, with independent feeds to each inlet of the cylinders, give very good results and the valves and cylinders on a number of superheater locomotives now running are successfully lubricated in this manner. Two lubricators are usually employed, with three feeds for each cylinder, two of the feeds going to the ends of the piston valves and one to the center and top of the cylinder barrel.

The temperature of saturated steam at 200 pounds pressure is 387°, and with 150° of superheat, the temperature of the steam will be 537°. It would appear that this is somewhat higher than the flashing point of the valve oil in regular use and it is probable that some of this is vaporized before the valves and metal surfaces are properly lubricated. This is offered as a possible explanation of the slight increase in oil consumption in lubricating valves and cylinders of locomotives equipped with superheaters.

The circulation of steam in the type of superheater which this company first developed was produced by an internal circulating tube, commonly known as a Field tube. The boiler or fire tubes were 3 inches O. D., the superheating tubes 1¾ inches O. D. and the circulating tubes 1 1-16 inches O. D. This style of superheater was the first one applied by the American Locomotive Company to a New York Central Atlantic type engine in June, 1904, and is illustrated in the *American Engineer* of September, 1904, page 338. This superheater is still in service, and the locomotive to which it is applied is running fast express trains between Albany and New York.

A similar arrangement with the same size tubes was soon after applied to some Canadian Pacific consolidations. For a few subsequent applications the fire or boiler tubes were increased to 3½ inches, with a view of raising the temperature by increasing the area of the flow of the gases.

In the majority of cases the later forms of superheater applied by the American Locomotive Company have been of the return bend system, with boiler or fire tubes 5 inches O. D., and four superheating tubes 1¼ inches O. D., 15-16 inch I. D., united in pairs at the fire-box end with return bends. A much larger number of locomotives have been equipped with this later arrangement than with the original circulating tubes, and some sixty equipped in this manner are now in successful service. An average superheat temperature of 130° has been usually obtained by this arrangement in passenger service. The temperature was taken at the steam chest by means of accurate instruments, and for this purpose high-grade thermometers with the bulbs immersed in tubes containing heavy oil were used.

With this degree of temperature substantial economies in fuel and water have been obtained. A later development of this style of superheater

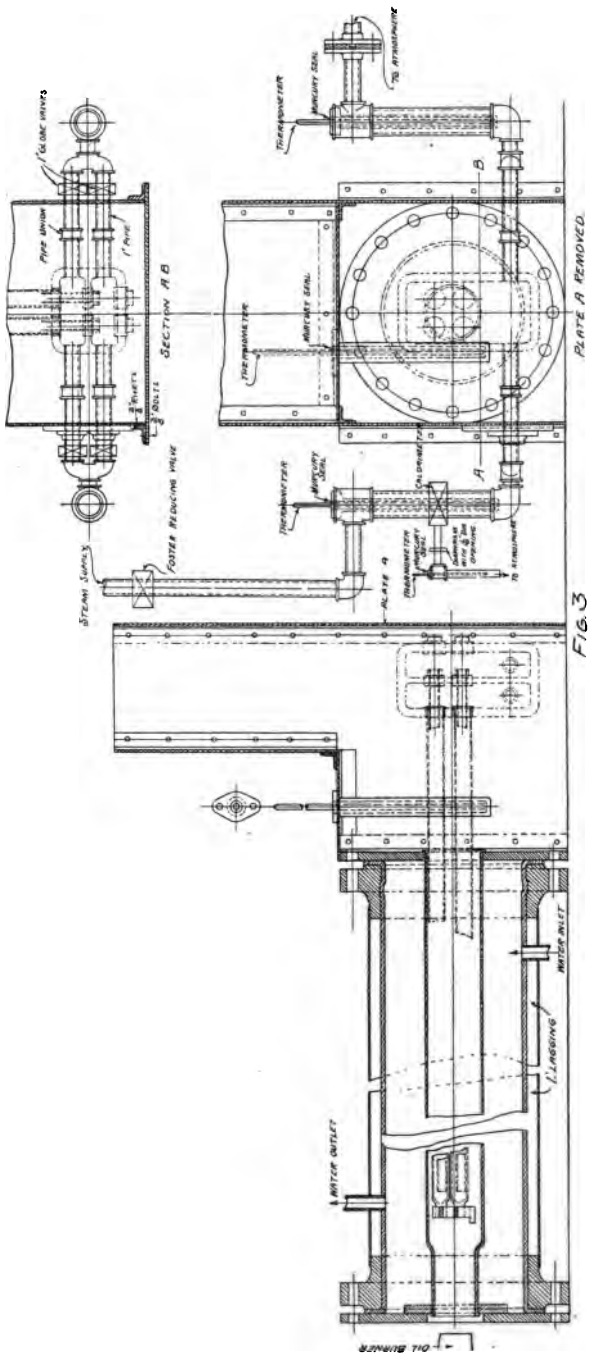

SECTION A B
PLATE A REMOVED
FOSTER REDUCING VALVE
STEAM SUPPLY
PLATE A
THERMOMETER
MERCURY SEAL
COLD WATER
WATER OUTLET
WATER INLET
OIL BURNER

FIG. 3

for atomizing the oil. Thermometers were inserted at different points to measure the temperature. The saturated steam was kept at a uniform temperature and arranged to enter and discharge through diaphragms of uniform dimensions. A calorimeter was used for determining the amount of moisture in the steam and the test generally conducted so as to eliminate, as far as possible, all errors. The general arrangement of the apparatus is shown in photographic views, Figs. 4 and 5.

FIG. 4.

The amount of superheat obtained was measured by high-grade thermometers, with bulbs immersed in heavy oil, and the efficiency of the different systems determined by the number of B. T. Us. absorbed by the superheated steam. Table, Fig. 6, gives a brief result of these tests, in which the return bend system, as in Fig. 1, is taken at 100. The original Schenectady superheater with the flow of saturated steam through the circulating tube and the superheated steam in the same direction as the flue gases, gave a figure of 39. With the direction of the flow reversed, the figure obtained was 70, which would appear to indicate that a substantial gain is effected by causing the saturated steam to flow in a direction opposite to the flue gases.

On the other hand, under certain favorable conditions, in which the fuel causes no clogging up of the tubes, the original arrangement with 3-inch fire tubes has given very favorable results, an average temperature of between 105° and 110° at the steam chest being obtained, and the maximum temperature at times 25° or 30° in excess. In a test extending over many trips, carefully made to eliminate as many errors as possible, a fuel saving of 17 to 19 per cent was effected.

A prairie type passenger engine equipped with the later form of return bend superheater has been running on the L. S. & M. S. Ry. in passenger

service for several months, and while no accurate tests have been made, it is the opinion of the men in close touch with this engine that there is a saving in fuel and water of at least 15 per cent, and a substantial improvement in the running and operation of this engine. It is considered a very lively and fast engine, and is able to handle the heavy passenger trains with apparently greater ease than similar engines not so equipped.

FIG. 5.

On the Canadian Pacific Railway fifty-five ten-wheel freight engines have been equipped by the American Locomotive Company with a similar form of superheater, but some improvements have since been made in the joints and bolting. These are working well and showing economies at least equal to compounds.

Absolute perfection of detail is too much to expect in so short a time in the application of so radical a principle. Since the theory of a superheater was presented before this Association last year, facts from experience have become available which tend to confirm the opinion that future locomotive development is to include this principle.

This opportunity to comment upon the very satisfactory attitude of the

SOME RESULTS OF SUPERHEATER TESTING APPARATUS.

	No. of Tests Aver'g'd	Steam per Min. in Lbs.	Oil per Min. in Lbs.	Efficiency.	Superheat in Degrees Fahr.	Comparative Value.
Return Bends.....	3	11.734	.258	.01702	124.3	100
Schenectady, Regular.....	5	12.166	.370	.00671	58.9	39
Schenectady, Reverse.....	5	13.861	.349	.01197	117.6	70

FIG. 6.

Canadian Pacific Railway toward superheating must not be allowed to pass. At the present time railroads owe much to Mr. Vaughan for his courageous adoption of superheating on so large a scale, because it is only through large scale experiments that the information so greatly needed in matters of this kind can be secured.

At the present time superheaters are in service upon or being built for the following railroads:

Canadian Pacific	186
Chicago & North-Western	2
Chicago, Rock Island & Pacific	6
Lake Shore & Michigan Southern	2
Delaware, Lackawanna & Western	1
Chicago, St. Paul, Minneapolis & Omaha	3
Michigan Central	1
Boston & Maine	1
Northern Pacific	3
	205

and while some reports are better than others, the resultant of all the trials justifies the statement that railroads are perfectly safe in taking into consideration this feature for new power and for renewals of old power.

In connection with superheating it is possible to reduce boiler pressure without loss of power and in further experience this may become an important factor. Thus far superheaters have been applied to existing designs and the application has, in general, been an adaptation of superheating, but the time has come for a consideration of designs prepared especially for superheating. This may or may not result in a reduction of boiler pressures, but the possibility of reducing pressures becomes important in the application of superheaters to old locomotives, the boilers of which are weakened by age and unequal to the task of maintaining high pressures. For example — by equipping an old locomotive, originally overcylindered, with a superheater, the boiler pressure may be reduced to a reasonable extent without sacrificing power, thus adding some years to the effective life of locomotives, provided the cylinders and running gear are in condition to warrant the expenditure. This phase of superheating has not received the attention which its important merit deserves.

The attention of the writer was recently called to an operating advantage offered by the superheater which, perhaps, has not been fully appreciated. In the case referred to it is found possible for the superheater locomotive on a long passenger run to pass one of the customary coaling and watering stations without stopping. On this particular road the single application of superheating makes it exceedingly popular with operating and mechanical officials. If trains hauled by superheater locomotives are not increased in weight it may become possible to effect a material saving in certain localities from the economy thereby obtained.

Whether or not present types of superheaters prevail is not important in the present discussion. It is important for the principle of superheating to receive attention particularly from those who are now facing or are soon to face the necessity of increased capacity of locomotives with increasing weight and other limitations. From the standpoint of capacity the superheater seems to have come opportunely, because while it may be possible to increase the weight of both passenger and freight locomotives, it is desirable to have recourse to some other means for increasing capacity. As the country builds up into larger communities, traffic requirements are sure to increase, and anything which tends toward an increase of locomotive capacity should be earnestly welcomed. From the standpoint of augmented capacity, superheating is of great interest to American railroad men at the present time.

The first successful superheater applied on this continent was in 1899. At the present time 205 locomotives are equipped, or being equipped, with this device. That superheating has made such progress in so short a time is, of itself, remarkable, and it is fair to expect its satisfactory development from present experience.

Next in order is the topical discussion on (A) "The Relation of Roundhouse to Shop and Road"; (B) "The Best Roundhouse Organization for Properly Taking Care of Locomotives," to be opened by Mr. S. W. Miller. Is Mr. Miller present? If not, we will proceed to the next, which is, "Distortion of Wheel Centers and Tires Out of Round Due to Heavy Counterbalance on 100-ton Engines," to be opened by Mr. George W. West.

DISTORTION OF WHEEL CENTERS AND TIRE OUT OF ROUND.

MR. G. W. WEST (N. Y. O. & W.): In the year 1900 the New York, Ontario & Western Road built one 100-ton engine of the simple consolidation type with Richardson balance valve, cylinders 21 by 32 inches, 48-inch wheel centers. After using it on our heaviest grades one year, we decided it was about what was needed and we had four additional ones built after the same pattern. We have added to the number until we now have twenty. When these engines were new, or after they had been through the shops receiving general repairs, they were fine riding engines, and not until their tires were worn down to about 2¼ inches in thickness did we begin to have complaints of hard-riding engines. Nor did we find tires worn out of round to any extent until they had been turned the second

time, and it was not until we had occasion to send one of these engines to the manufacturers for general repairs that we discovered that the wheel centers were out of round. It has been our practice to true up the outside on new as well as old tires, and the locomotive company did not true up the new tire they applied, and every engineer complained of its hard riding. We removed the wheels, tested the tire, and found centers out of round as shown on print.

Mechanical engineers, in designing cast-steel parts for locomotives and carwork, are making the same mistake they made in substituting malleable for cast-iron parts; in a great many cases simply changing the material with no greater factor of safety.

I have some cuts that I would like to call your attention to, showing how the wheel is compressed between the counterbalance and the hub. We found it varying from 1-32 to 3-32 inch. If you measure some of the wheels, even with the new tire on, you will be surprised at the result. These were discovered after the new tire 3 inches thick has been put on these wheels. The locomotive company put on the new tire and we sent it out. The men complained of heavy riding, we measured the tire and we found these dimensions. The smallest variation was 1-32 inch, and it ran up to 3-32 inch.

MR. E. W. PRATT (C. & N.-W.): Were these dished wheel centers?

MR. WEST: Very little dished.

MR. PRATT: How would the center of the rim and the line of the spoke compare with the center of the tire?

MR. WEST: They were flattened between the counterbalanced weight and the crank hub.

It does not seem to me, Mr. President, that there is any necessity for discussion on this subject. I think we are losing valuable time. The diagrams which have been passed around show the points explained in the discussion.

MR. PRATT: I move that the discussion be closed. (Carried.)

THE PRESIDENT: We will now take up the topical discussion: "To What Extent Should an Engine Be Repaired in the Main

Shop and What Class of Repairs Could Be Made to Advantage in the Roundhouse?" To be opened by Mr. C. A. Seley.

REPAIRS OF ENGINES IN MAIN SHOP AND ROUNDHOUSE.

MR. C. A. SELEY (C. R. I. & P.): It is quite a general custom, when engines go into the main shop for general repairs, that these engines are completely dismantled from one end to the other. In some instances this may be necessary, but in a great many cases, perhaps a majority of cases, it is not necessary. It is quite probable that the injector was in thorough working order when the engine went into the shop. Why should it be removed? The same thing applies to the valve and cylinder lubricators and all cocks in the cab, to the air pumps, and this can be extended to the cylinder packing and the valve packing. Assuming the statements just made are logical, it would be reasonable to suppose that these parts should not be disturbed when engines are passing through the shop.

To more clearly state this idea let us cite an example in regard to the work necessary in case a piston and its parts are in good order and removed, as is our custom. The heads are taken down, the pistons taken out, the piston taken to the lathe, the rods turned and the diameter is reduced. A great deal of care is exercised to make a polish which will perhaps be not as good as the piston had when it went into the lathe. After it is replaced it requires new packing, and a great deal of this work is apparently wasted.

There is a possibility in going through an engine of saving from $100 to $250, perhaps, by not taking down parts merely for the opportunity of putting them back again. This amount, applied to the number of engines held in a large shop, will make a very considerable sum. Where the reduction of expenses in maintenance of locomotives is carefully watched, it is thought that advantage can be taken of this matter, and it appears to us that if the condition of an engine is accurately ascertained before shopping, and the Master Mechanic or others in charge of the engine, in sending it to the shop, shall give the shop full instructions as to what is to be repaired and what is to remain untouched, a very large saving can be effected.

THE PRESIDENT: This is a very interesting subject, and it is now open for discussion.

MR. G. R. HENDERSON: I heartily agree with Mr. Seley in the matter, and think that the subject presented by him has been very well treated. Several years ago I adopted the system of having an individual card for each engine, and when the engine went out of the shop the cost of repairs and the general nature of repairs were stated on the card. The next time the engine was a candidate for the shop, it was reported beforehand, and it was a simple matter to look up and find out how much it had cost the last time it was repaired, and the work which the engine had done since it was last in the shop. The mileage made by the engine was recorded on the card, and you could tell at once whether the engine had made a sufficient mileage to warrant general repairs. If we found that the mileage performed by the engine since it was last shopped was comparatively small for the cost of the repairs, we sent instructions to the shop that only such work should be done upon the engine as was actually necessary, and called attention to the fact that only a small mileage had been made for the comparatively large cost of the previous repairs. We found that some shops had a habit of taking everything off the engine and scrapping parts that could be used and made to serve another term or two without any defect to the service. I think much money can be saved by giving attention to these details.

MR. J. F. WALSH (C. & O.): There is so much good horse sense in what Mr. Seley says that it does not seem to me there is much room for discussion. He has called our attention to the fact that many things are taken down when the engine comes into the shop, simply for the purpose, apparently, of putting them up, which is a fact, and I think all we have to do is to profit by the suggestions brought out by Mr. Seley. I think they are very timely and very valuable.

MR. E. W. PRATT (C. & N.-W.): I believe this Association should take a practical step toward arriving at the desired results indicated by Mr. Seley, in appointing a committee to collect the various forms used by the various railways for reporting work to be done on the engines which are to undergo repairs. The

diversity of such reports is very great at present, and I have talked with several representatives of the different railroads, and they do not seem to be exactly satisfied with their form of reports. I believe it would be conducive of desirable results to have a committee appointed to prepare a form of report as recommended practice, covering details in connection with engines to be overhauled.

MR. F. H. CLARK (C. B. & Q.): It seems to me that is a very good suggestion. There is undoubtedly a lot of information to be obtained in some such way, and I would move that the matter be referred to the Executive Committee for action. (Motion carried.)

MR. J. A. PILCHER (N. & W.): There is one point which I think should be mentioned in this connection — what effect does the system of piecework prices in the erecting shop have on the number of parts taken down and replaced? I think that is a good point to take into consideration in any further discussion of this matter.

MR. WEST: I move that the discussion be closed.

THE PRESIDENT: We will now take up the next topical discussion: "Relative Advantage of the Piston Valve as Compared to the Slide Valve," to be opened by Mr. E. A. Miller.

PISTON VALVES VS. SLIDE VALVES.

MR. E. A. MILLER (N. Y. C. & St. L.): In considering the relative value of the piston valve as compared with the balance slide valve I would first call your attention to the report, made to this Association in 1904, of tests made for steam leakage of both the piston and slide valves.

The test of four piston-valve engines made on the Norfolk & Western Ry. shows first, that old rings, old bushings and old valves in good condition showed an average leakage of steam through valves condensed of 267 pounds of water; second, with new rings, new bushings and new valves, 539 pounds of water; third, with new rings, new bushings and new valves in good condition, 288 pounds of water; fourth, old rings, old bushings and old valves in good condition, 399½ pounds of water, or an aver-

age steam leakage of 374 pounds of water per engine for one hour.

Two slide-valve engines tested on the Norfolk & Western Road showed an average leakage of 459 pounds of water per hour, or 85 pounds more than the average of piston-valve engines. The report of nine piston-valve engine tests on the L. S. & M. S. Ry. on a machinery mileage of from 13,000 miles per engine to 77,000 miles per engine, shows the lowest steam leakage to be 540 pounds of water per hour, and the greatest steam leakage to be 2,880 pounds of water per hour. Average machinery mileage of the nine engines is 39,700 miles per engine. The average steam leakage of the nine engines was 1,654 pounds of water per hour.

The report of the eight slide engines on the L. S. & M. S. Ry. shows a machinery mileage of 26,750 miles per engine, and an average steam leakage of 1,384 pounds of water per engine, for one hour, or 270 pounds less per engine for one hour than the piston-valve.

While this report is favorable to the slide-valve as compared with the piston-valve so far as steam leakage is concerned, I would call your attention to the fact that the tests made by the committee for valve leakage show both the piston and slide valves leaking more steam than should be allowed.

An interesting part of the test made by the N. & W. Ry. is the table showing 222 engines equipped with piston-valves — number of rings per engine, 12; number of rings broken in sixteen weeks, 266; number of rings removed for wear, etc., in sixteen weeks, 314; total number of rings removed in sixteen weeks, 580.

This shows a considerable increase in the cost and work of running repairs for the piston-valves as compared with the balance slide-valves, which are usually run from shopping to shopping of engine without renewal of parts. Any change in valves or other parts of locomotive that will increase the running repair work or the time the engines will be held out of service should receive very careful consideration before being adopted as recommended practice.

In testing two of our piston-valve and two of our balance

slide-valve engines for valve leakage, we have the following results:

Engine 141, piston-valve, steam pressure 200 pounds, machinery mileage 36,850 miles, valves placed central. Right valve, steam leakage (condensed), 280 pounds of water per hour; left valve, steam leakage 343 pounds of water per hour.

Second test: Right valve placed 5/8 inch ahead of center, left valve placed 5/8 inch back of center. Right valve, steam leakage 212 pounds of water per hour; left valve, 351½ pounds of water per hour. Packing rings in good condition, bushings worn 1-16 inch oblong, also 1-64 inch hollow.

Engine 134, piston-valve, steam pressure 200 pounds, machinery mileage 55,770 miles, valves placed central. Right valve, steam leakage 325 pounds of water; left valve, steam leakage 300 pounds of water for one hour.

Engine 45, balance slide-valve, steam pressure 180 pounds, machinery mileage 33,846 miles, valves placed central. Right valve, steam leakage 148 pounds of water for one hour; left valve, steam leakage 156 pounds of water for one hour. While making this test, the right valve was moved backward and forward about 5/8 inch, by moving reversed lever. Valves not examined.

Engine 49, balance slide-valve, steam pressure 180 pounds, machinery mileage 33,116 miles, valves placed central. Right valve, steam leakage 150 pounds of water for one hour; left valve, steam leakage 122 pounds of water for one hour.

The valves and seats, also balance-strips and plates of this engine, examined and found in first-class condition.

In all of these tests the exhaust-pipe opening was locked so that every particle of steam leaking through valves was condensed.

In this test the two piston-valve engines were from ten engines of the piston-valve class in freight service. The two balance slide-valve engines were also from ten engines of the balance slide-valve class, and in both cases the engines were taken for testing just as they happened to come into the terminal when test was desired.

While the average machinery mileage of the two piston-valve engines was 46,310 miles per engine, and the steam pressure, 200 pounds, was compared with 33,482 miles and steam pressure of 180 pounds for the slide-valve engines, nevertheless, the average of steam leakage of 624 pounds per engine for piston-valves as compared with 288 pounds for slide-valves is very much in favor of the balance slide-valve engine.

This test was with the plain ordinary Richardson balance slide-valve and the piston-valve with central steam admission snap rings, as furnished by the American Locomotive Company.

In conclusion, would say that I have not had any experience with the improved piston-valve, such as the Wilson semi-plug valve, or the Wilson improved gridiron balance slide-valve, which I understand are giving excellent results.

THE PRESIDENT: This subject is now open to general discussion.

MR. WM. MCINTOSH (C. R. R. of N. J.): I would ask Mr. Miller just one question: that is, when these engines went into service, prior to the test being made, did the slide-valve engine have the valves faced up in the usual manner, and did the piston-valve engine have the piston chamber bored and new ring equipment provided?

MR. E. A. MILLER: In the case of the slide-valve, the valve seat, the balance strips, plates and so forth were newly fitted, and in the case of the piston-valve the rings were new, but the bushings were not bored out. The engines had only been in service about a year at that time.

MR. WM. MCINTOSH (C. R. R. of N. J.): I asked the question for the reason that we have a large number of piston-valve engines and they at first apparently wore so smoothly and nicely in the steam chambers that for a considerable period we concluded they were all right and did not consider it necessary to bore the chamber, but on later examination we found they were wearing more or less, the same as any chamber must necessarily wear in service, and we found it was advisable to true the chamber up at reasonable intervals in order to obtain satisfactory results and avoid excessive leakage, which is otherwise bound to develop.

MR. J. F. WALSH (C. & O.): Like the subject of grease for lubrication, there are several features to be taken into consideration in the use of the piston-valve as compared with the slide-valve. We have seventy-five engines, 22 by 28-inch engines, weighing 100 tons, and carrying 200 pounds of steam, equipped with slide-valves, 23 inch valves. It was next to impossible for the enginemen to handle these engines in the switching service in the yards running in and out of the coal mines, and when we had occasion to put an engine of that character in the yard it was utterly impossible to get anything like a day's work out of the engine. Again, working these engines under 200 pounds pressure — the slide-valve engine — it was so hard to handle the engines, that every time the engineer attempted to unlatch the lever, to cut her back or drop her down, as the case may be, he was threatened with an experience which is almost equal to a very severe kick from a mule. We had to provide some easier means of handling these engines, and in order to do that and maintain the speed of the engine under pressure, we took up the subject of piston-valve engines.

We have about 150 piston-valve engines. These engines have been in the service all the way from six months to three years. We have had very little trouble from the cutting out of either valve or chamber bushings, not as much trouble, nearly, as we had in renewing balance strips in the ordinary D-valve. We have comparatively little trouble with them as far as valve steam leakage is concerned. You all know that — they are central admission valves, consequently all you get at the valve stem end is the exhaust and the leakage from that amounts to nothing, whereas with the D-valve engine you have almost a constant bad leakage from the valve stem packing. We do not know what it is to have leaky steam chests on the piston-valves, and did not know what it was to have tight ones on the D-valve. So much in favor of the piston-valve, particularly if it is given anything like the attention that should be given it. There is so much in favor of the piston-valve, as against the D-valve, that there is not much argument as to which is the best. The wear on the valve motion in the case of the piston-valve is nothing in comparison with what it is in the case of the D-valve engine. Such a thing as a distor-

tion of the eccentric rods, which we are commonly subjected to with the D-valve engines, is almost an unknown quantity in the piston-valve engine. I think there is so much to be said in favor of the piston-valve engine, in spite of the fact, according to Mr. Miller's figures, that there is a serious steam leakage, that it is to the advantage of all concerned to use the piston-valve engine.

MR. F. SLATER (C. & N.-W.): I indorse what Mr. Walsh has just said and would like to say in regard to the piston-valve for large power — large engines carrying high pressure — that we found in using the large slide-valve it is almost impossible to operate the engine. The cost of facing the valve is large, and it has to be done frequently. I know from personal experience that a piston-valve engine can be kept in shape with very little work. In the case of an engineer who has had experience with the piston-valve, he can report a broken ring and locate it so that you will know where to find it, and it takes only a few minutes to slip the valve out and spring in another ring and the engine is ready for service again. That can not be done with the slide-valve engine.

MR. JOHN PLAYER (Amer. Loco. Co.): I do not think the comparative measure of the leakage of the piston and slide-valve engine should be taken as the measure of the efficiency of the valve. It must be remembered that the length of the port in the piston-valve engine is nearly double what it is in the slide-valve engine. Consequently, in the case of a leakage measured by the efficiency of a port, the leakage of a piston-valve engine is considerably less than it would be in the case of a slide-valve engine.

MR. G. W. WEST (N. Y. O. & W.): I ask if any one present knows what valve is in the engine that took the special train over to Philadelphia yesterday afternoon? I was under the impression it was a slide-valve engine, judging from the engine which we saw at the station down there.

MR. F. M. WHYTE (N. Y. C.): I think Mr. Miller said that the pressure was 200 pounds on the steam side of the valve. I ask what was the pressure on the exhaust side of the valve?

MR. E. A. MILLER (N. Y. C. & St. L.): We did not measure these pistons for pressure.

MR. WHYTE: Probably it was near atmospheric pressure.

MR. MILLER: Yes.

MR. F. M. WHYTE: My opinion would be that while the figures obtained might be relatively correct, the amounts are not correct for ordinary operation of the locomotives. For instance, in passenger service there is 200 pounds pressure in the steam cylinder only a small part of the time, and for freight service, of course, that pressure is in the cylinder for a greater proportion of the time; the pressure on the other side of the valve, the exhaust pressure, is greater than what was experimented with, therefore, in service, the total leakage ought to be considerably less than the figures indicate.

MR. JOHN A. PILCHER (N. & W.): I happened to be on the committee that was referred to, as making the test in 1904. I made the test on the Norfolk & Western road. You will note in these particular tests on the Norfolk & Western road that the leakage of the piston-valves was less than the D or slide-valves. The experiments on the other roads seem to result otherwise. The engines tested at that time were engines taken at random as they came into the shop; some just as they were going out, and some just as they were coming in. In some cases, on the slide-valve engines, we were not able, with the apparatus we had, to tell just what the leakage was. In the case of the piston-valve engines, in fact, we put mercury gauges in the cylinders and also measured the leakage as it passed through the cylinder cock openings. In some cases on the slide-valve engines the mercury blew out and we could not tell the pressure, but in all cases on the piston-valve engines there was no trouble in registering the pressure due to the leakage. Instead of having at this time over two hundred engines with the piston-valves, we have something over five hundred engines with the piston-valves, and all that have been put on the road since the time we made the test have had piston-valves.

MR. G. E. PARKS (Mich. Cent. Ry.): I think at this time it would be well to bring before the convention the report of the

Committee on the Lubrication of Piston Valves. With the piston-valve the engineer can not tell readily whether his valve is receiving the proper amount of oil, and that, no doubt, causes more or less broken rings and other parts, which is not true of the slide-valve engine. We took some indicator cards of a piston valve locomotive at one time, and in order to tell the effect of running the valve dry, one side of the locomotive was run practically without oil for fifty miles, and so far as the reverse lever was concerned, we could tell no effects from the dry valve, but the man taking the indicator card could see a noticeable difference in the travel of the valve stem.

MR. E. A. MILLER (N. Y. C. & St. L.): In reply to some of the remarks which have been made in regard to the lowering of cost of repairs by using the piston-valve, we received thirty consolidation engines with solid piston-valves, built by the American Locomotive Company, and very soon after being placed in service a large breakage developed of eccentric straps, transmission bars, eccentric rods and rockers as shown by the following figures:

Type of engine, 8-wheel freight, balance slide-valve.— Number of engines in service, 15; failures, 4; average number of failures per engine, .20.

Ten-wheel freight, balance valve.— Number of engines in service, 55; number of failures, 20; average failure per engine, .36.

Mogul slide-valve freight engine.— Number of engines in service, 20; number of failures, 2; average failure per engine, .10.

Consolidation piston-valve.— Number of engines in service, 30; failures, 47; average failures per engine 1.56, or 64.3 per cent failures of the piston-valve as compared with 2.7 per cent for the Mogul, 27.5 per cent for the ten-wheel engine, and 5.5 per cent for the 8-wheel engine, balance slide-valves.

These are the facts as shown by our experience in the use of the solid piston-valves as compared with the balance slide-valves.

We changed the solid piston-valves and put in the hollow piston-valves, reducing the breakage very much.

MR. C. A. SELEY: I move that the discussion be closed.

(Carried.)

THE PRESIDENT: The next business will be the topical discus-

sion on "Is the Walschaert valve-gear an improvement over the Stephenson link movement?" to be opened by Mr. George W. West.

MR. G. W. WEST: I wrote the Secretary I knew nothing about that subject whatever, and that it was a mistake to put me down to open the subject.

THE SECRETARY: I received a letter from Mr. West to that effect after the program was printed and too late to assign it to another member.

THE PRESIDENT: The next in order is the report of the Committee on Subjects. The members have had the report of that committee, which has suggested the subjects which this convention has discussed to a certain extent. It has also submitted proposed subjects for reports for the next convention, with names for committees; also subjects for individual papers, with suggestion of the names of the parties to prepare them. The report is as follows:

REPORT OF COMMITTEE ON SUBJECTS.

To the Members:

The Committee on Subjects present the following:

NOON-HOUR TOPICAL DISCUSSION, CONVENTION OF 1906.

1. Is not a boiler pressure of 185 pounds better than 200 pounds for locomotives?
Opened by Dr. W. F. M. Goss.

2. The necessity of proportioning brake pressure to wheel loads.
Opened by G. L. Fowler.

3. Is it practical to use the Prosser tool in roundhouse running repairs?
Opened by F. R. Cooper.

4. Grease vs. oil in driving box cellars.
Opened by F. H. Clark.

5. (a) Relation of roundhouse to shop and road.
(b) The best roundhouse organization for properly taking care of locomotives.
Opened by S. W. Miller.

6. Distortion of wheel centers and tires out of round due to heavy counterbalance on 100-ton engines.
Opened by George W. West.

7. To what extent should an engine be repaired in the main shop and what class of repairs could be made to advantage in the roundhouse?
Opened by C. A. Seley.

8. Relative advantage of the piston valve as compared with the slide valve.
Opened by E. A. Miller.

9. Is the Walschaert valve gear an improvement over the Stephenson link movement?
Opened by George W. West.

COMMITTEE REPORTS, 1907 CONVENTION.

1. The comparative arrangement for coaling stations.
F. F. Hildreth, F. H. Clark, J. B. Barnes.

2. Submit a blank form for use at terminals to give history of the movement of every locomotive from the time it leaves its train until it takes its next train. Object: to secure closer coöperation between the mechanical and operating departments.
G. M. Basford, R. D. Smith, R. P. C. Sanderson.

3. What thickness of tires is the most practical for locomotive driving wheels—3 inches, 3½ inches or 4 inches thick? Why?
W. T. Fitzgerald, John Howard, H. F. Bentley.

4. Results of different valve gears on locomotives.
C. A. Seley, A. S. Vogt, G. H. Haselton, Robert Quayle.

5. Proper allowance for fitting axles and crank pins to driving wheel centers and method of registering the pressure.
S. W. Miller, L. R. Pomeroy, S. M. Dolan.

6. Pay for shop and roundhouse labor and comparative merits of day work, piece work, bonus or other systems.
David Van Alstyne, J. F. Deems, W. R. McKeen, Jr.

7. The proper spacing of flues in high pressure boilers.
Charles E. Fuller, H. J. Small, F. J. Cole.

8. Supervision in larger locomotive repair shops.
G. W. Wildin, H. H. Vaughan, J. B. Kilpatrick.

9. Boiler shop area in square feet, per pit of erecting shop, including cranes, machine and tool equipment.
T. Rumney, A. C. Deverell, A. E. Manchester.

INDIVIDUAL PAPERS, 1907 CONVENTION.

1. Locomotive failures, records and results of keeping them.
Paper by W. E. Dunham.

2. Superheating and compounding from a standpoint of locomotive economy.
Paper by T. A. Foque.

3. Shop cost systems and effect of shop schedule on output and cost of locomotive repairs.
Paper by A. Lovell.

4. Causes for leaky flues.
Paper by M. E. Wells.

R. D. SMITH, Chairman,
G. W. WILDIN,
C. H. QUEREAU,
Committee.

LINCOLN, NEB., February 7, 1906.

THE SECRETARY: I move that the report of the Committee on Subjects be referred to the Executive Committee for consideration when it meets to formulate the program for the next year.

(Motion put, seconded and carried.)

THE PRESIDENT: Next is the report of the Committee on Correspondence and Resolutions. Mr. Basford is chairman.

MR. G. M. BASFORD: I am informed that this year the registration amounted to about four thousand. I could not get the exact number. It also appears that the number of exhibits is some fifty more than any previous year.

The Committee on Resolutions makes the following report:

WHEREAS, This convention has been more than usually successful in attendance, in the character of reports and discussions, and in the large number of important and interesting exhibits; therefore, be it

Resolved, That the hearty thanks of the Association be extended to the President, for his able and encouraging address; to the officers of the Association, and especially to the Secretary, for his conscientious and efficient service; to the technical committees and the authors of papers for their painstaking presentation of subjects for discussion; to the Committee of Arrangements for providing so well for the convention; to the Baldwin Locomotive Works for courtesies extended and arranging for the visits of the members to their plant in Philadelphia; to the Philadelphia & Reading Railway for the special train provided for the occasion;

to the hotels for their hospitality and comforts provided; to the railroads and to the Pullman Company for the courtesies extended; to the Supply Men's Association, and especially to Mr. L. B. Sherman, the able, efficient and courteous secretary; to the Technical Press, and especially to the *Daily Railway Age* for interest in and aid to the Association.

MR. F. H. CLARK (C. B. & Q.:) I move the adoption of the resolution.

(Motion put, seconded and carried.)

THE PRESIDENT: The next in order is the election of officers. You will prepare your ballot for the office of President. I will appoint as recording tellers Mr. G. W. West and Mr. P. H. Peck, and as collecting tellers, Mr. J. A. Turner, Mr. F. H. Clark, and Mr. W. C. Squire.

Have all the members voted for President? If so, I declare the balloting closed for the office of President; and I suggest that the members prepare their ballots for the office of First Vice-President.

The tellers' report upon the vote for President was as follows: Eighty votes cast; necessary for choice 41, of which there are 78 votes for J. F. Deems and 2 votes for Mr. H. F. Ball.

MR. P. H. PECK: I move that the Secretary cast one ballot as the unanimous vote of this convention for Mr. Deems for the office of President.

(Question put, seconded and carried.)

THE SECRETARY: I take pleasure in casting the unanimous ballot of this Association for Mr. Deems for President of the Association.

THE PRESIDENT: It gives me great pleasure to announce that Mr. J. F. Deems has been elected President of the American Railway Master Mechanics' Association for the ensuing year.

Have all the members voted for First Vice-President? If so, I declare the balloting closed.

Kindly prepare your ballots for the office of Second Vice-President while the ballots are being counted.

The tellers report the votes cast for First Vice-President as follows: Eighty-five votes cast; necessary to choice 43; of which Mr. McIntosh received 78, Mr. F. H. Clark 1, Mr. Marshall 1, Mr. Walsh 1, Mr. Wildin 1, Mr. Vaughan 2.

MR. P. H. PECK: I move that the Secretary cast one ballot as the unanimous vote for Mr. Wm. McIntosh as First Vice-President of this Association.

(Motion put, seconded and carried.)

THE SECRETARY: I have pleasure in carrying out the orders of the Association in regard to the election of Mr. Wm. McIntosh as First Vice-President.

THE PRESIDENT: It gives me great pleasure to announce that Mr. Wm. McIntosh has been elected First Vice-President of the American Railway Master Mechanics' Association for the ensuing year.

Prepare your ballot for Third Vice-President.

Have all voted for the office of Second Vice-President? If so, I declare the balloting closed.

Mr. West, for the tellers, made the following announcement as to the ballots cast for Second Vice-President: Eighty votes cast, necessary for choice 41, of which Mr. Vaughan received 73, Mr. Wildin 1, Mr. Wilson 1, Mr. Clark 2, Mr. McIntosh 2, Mr. Hancock 1.

MR. PECK: I move that the Secretary cast a ballot as the unanimous vote of the Association for Mr. H. H. Vaughan for the office of Second Vice-President.

(Motion put, seconded and carried.)

THE SECRETARY: I have carried out the orders of the Association and have cast the ballot for Mr. H. H. Vaughan for Second Vice-President for the ensuing year.

THE PRESIDENT: It gives me great pleasure to announce that Mr. H. H. Vaughan has been elected to the office of Second Vice-President of this Association for the coming year.

Have all voted for the office of Third Vice-President? If so, I declare the ballot closed.

MR. JAS. MCNAUGHTON (Amer. Loco. Co.): I propose the name of Mr. J. Snowden Bell, as an Associate member of this Association. (Motion seconded by Mr. Walsh and Mr. Ployer.)

THE SECRETARY: A proposition for Associate membership is made at one convention and lies on the table until the next con-

vention. This proposition will therefore lie on the table until the convention of 1907, when it will be balloted on.

MR. G. W. WEST: The tellers have to report as to the office of Third Vice-President as follows: Eighty-four votes cast; necessary to choice 43; of which Mr. Wildin received 37, Mr. H. H. Clark 24, Mr. Curtis 14, Mr. Quereau 2, Mr. Chambers 1, Mr. Manchester 4, Mr. Bentley 2.

THE PRESIDENT: There being no choice, please again prepare your ballots for Third Vice-President.

MR. G. W. WEST: I have to report upon the second ballot for Third Vice-President as follows: Eighty-two votes cast; necessary to choice 43, of which Mr. Wildin received 46, Mr. Clark 17, Mr. Whyte 3, Mr. Manchester 2, Mr. Goss 1, Mr. Curtis 13.

MR. P. H. PECK: I move that the Secretary be instructed to cast one ballot for the unanimous election of Mr. G. W. Wildin to the office of Third Vice-President. (Motion put, seconded and carried.)

THE SECRETARY: It has been done.

THE PRESIDENT: It gives me great pleasure to announce to you that Mr. G. W. Wildin has been unanimously elected Third Vice-President of the American Railway Master Mechanics' Association.

The next in order is the election of the Treasurer, for which you will prepare your ballot.

MR. E. W. PRATT: I move that when the ballot is taken for the Executive Committee, of the four members receiving the highest number of votes, the first three be declared elected for the term of two years and the fourth for the term of one year. (Motion carried.)

MR. G. W. WEST: The tellers have to report upon the vote for Treasurer as follows: Forty-four votes cast, of which Mr. Angus Sinclair received the full number.

THE PRESIDENT: It gives me pleasure to announce that Mr. Angus Sinclair has been unanimously elected Treasurer of the American Railway Master Mechanics' Association.

THE SECRETARY: I would state that the names of Messrs. Wildin, Seley and Mitchell are retained as members of the Executive Committee; those retiring, Messrs. Manchester, Walsh and F. H. Clark. Mr. Wildin being elected Vice-President, is not eligible to hold office as an Executive member.

MR. G. W. WEST: The members receiving the highest number of votes for the Executive Committee are as follows: Mr. Clark 19, Mr. Fuller 19, Mr. Curtis 11, Mr. F. M. Whyte 8.

MR. P. H. PECK: I move that the Secretary be instructed to cast one unanimous ballot for the election of the four members receiving the highest number of votes for the Executive Committee.

THE SECRETARY: I have carried out the instructions of the Association, and have cast a unanimous ballot for the gentlemen named for their respective offices.

THE PRESIDENT: I take pleasure in announcing to you that the following have been elected as Members of the Executive Committee, the first three for two years and the last one for one year: F. H. Clark, C. E. Fuller, T. H. Curtis and F. M. Whyte.

THE PRESIDENT: Before surrendering the gavel to my worthy successor, I desire to assure you that it has been extremely gratifying to me to have been your presiding officer during this most successful convention. It has been a successful convention in every respect; from the standpoint of the high-grade character of the papers presented, from the standpoint of attendance and that of discussion. I wish to thank you all for the interest you have taken in the convention, because if you had not taken an interest in it the convention would not have been a success. I also wish to thank the Secretary and others who have had to do with the management of affairs, for their kind coöperation, and I take great pleasure in introducing our new President, Mr. J. F. Deems.

MR. J. F. DEEMS (N. Y. C.): I take this place with some misgivings, and I realize that I have a pretty hard road to follow in keeping the pace set by the gentleman who has preceded me, for I realize that it is pretty hard to follow a ball, especially a high-ball, and I think probably the best thing I can do will be to train strenuously during the coming year, and with the kind

assistance of our friends on the supply side of the house, I think I can get along very well in that line. I feel very grateful for this recognition, and I feel especially that the success of the convention depends upon the work of the members, and not on anything that the President can do. I trust that I shall receive the earnest assistance of the members of the Association that I have been associated with for so many years, and towards whom I feel so kindly, and as I hope, at least some of them do towards me. If I can see the next convention rounded out as successfully as this one has been, I shall indeed feel very much gratified. I thank you for your courtesy.

MR. H. H. VAUGHAN (Can. Pac.): A very pleasant duty devolves upon me now in proposing that the vote of this Association be tendered to Mr. Ball for the able and efficient manner in which he has filled the position of your President during the past year. We owe our thanks to Mr. Ball for his thoughtful and inspiring address, an address which will give us food for thought for some time to come, and which heralds the way for the greater opportunities and accomplishments of motive-power men. We owe our thanks to him for the leadership he has manifested in our committee meetings and convention, and especially so for his capable and fair direction of the convention we have just concluded. Gentlemen, I ask your hearty coöperation in passing him a sincere vote of thanks.

THE SECRETARY: At the opening of the Master Car Builders' Association a gentleman connected with the Supply Men's Association was appointed night mayor of Atlantic City. I believe he has discharged the duties of his office to the satisfaction of all concerned. He is, however, anxious to secure recognition on the floor of this convention that he may give an account of his stewardship. I would bespeak the privileges of the floor to Mr. F. K. Shults, President of the Supply Men's Association, who is also night mayor of Atlantic City.

MR. SHULTS: Mr. President and Gentlemen: I know that I am on the wrong side of the fence, but I am looking for a ball; having found the same I will proceed to play the game for which I have been in training for several weeks.

Mr. Ball, though you are no longer the highball of the Master

Mechanics' Association, you certainly are still high in the esteem and confidence of those who have the pleasure to know you. To place this Past President's badge in your possession is a last official act, than which no pleasanter finish could be asked for. Our best wishes go with you in your future work.

MR. BALL: Mr. Shults, all I can say is that I am deeply appreciative and sensible of the honor you have conferred upon me in giving me this evidence of your esteem. I will not say any more, but simply desire to assure you of my deep appreciation.

Adjourned.

CIRCULAR RELATING TO LETTER BALLOT.

DEAR SIR,— At the convention of 1906 the following subjects were referred to letter ballot.

They are stated in paragraphs A, B and C below, and each member is requested to write "Yes" or "No" on the accompanying postal card and mail it to the Secretary, 390 Old Colony building, Chicago, Illinois.

A vote "Yes" will mean that the subject is to be adopted as indicated, and a vote "No" will mean that it is not to be adopted.

The votes will be counted August 31, 1906, and any votes received at the Secretary's office after that date will be excluded from the count.

All votes must be either "Yes" or "No" to be counted, as no qualified votes will be considered.

FITTINGS FOR LUBRICATORS.

The Committee on Locomotive Lubrication proposed a standard location of holding arm shoulder and oil and steam connection joint faces; also a system of fittings and joints for all connections. Fig. 1 proposes the location for connection of joints and holding arm. Figs. 2, 3, 4 and 5 show pipe joints and fittings, and Fig. 6 illustrates the holding arm proposed.

A. Do you favor the adoption of these devices as standard?

SPECIFICATIONS FOR LOCOMOTIVE CASTINGS.

The committee on the above subject, in accordance with instructions, submits two specifications, as follows:

SPECIFICATIONS FOR FOUNDRY PIG IRON.

The material desired under this specification is an open-grain foundry pig conforming to and graded by the following detail specifications:

Combined carbon	.40 to .70 per cent.
Manganese	.40 to .80 per cent.
Phosphorus	.40 to .80 per cent.
Sulphur, not over	.06 per cent.

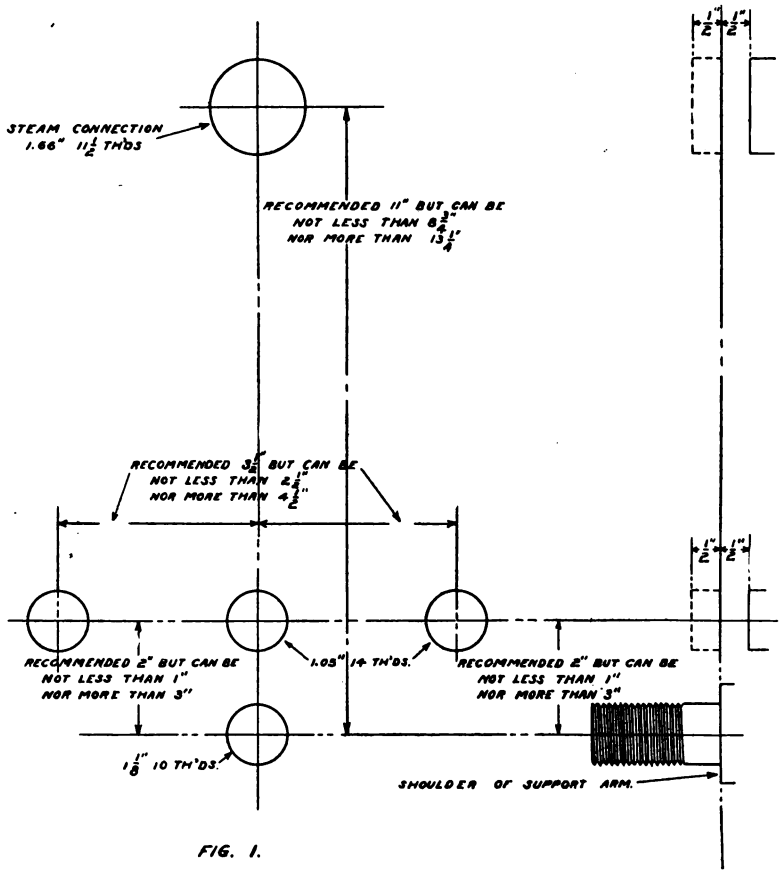

STEAM CONNECTION
1.66" 11½ TH'DS
RECOMMENDED 11" BUT CAN BE
NOT LESS THAN 6¾"
NOR MORE THAN 13¼"
RECOMMENDED 3½" BUT CAN BE
NOT LESS THAN 2½"
NOR MORE THAN 4½"
RECOMMENDED 2" BUT CAN BE
NOT LESS THAN 1"
NOR MORE THAN 3"
1.05" 14 TH'DS.
RECOMMENDED 2" BUT CAN BE
NOT LESS THAN 1"
NOR MORE THAN 3"
1⅛" 10 TH'DS.
SHOULDER OF SUPPORT ARM.
½" ½"
½" ½"

FIG. 1.

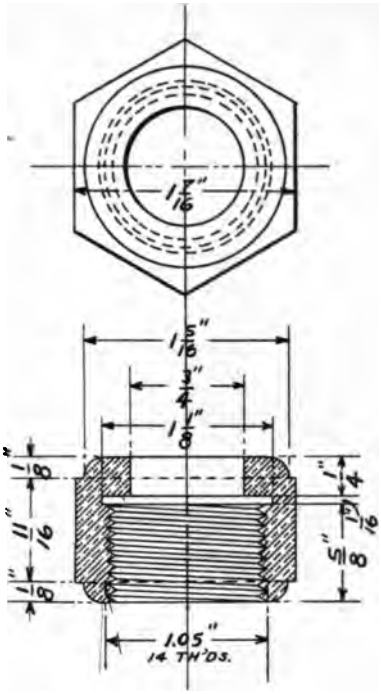


FIG. 2.

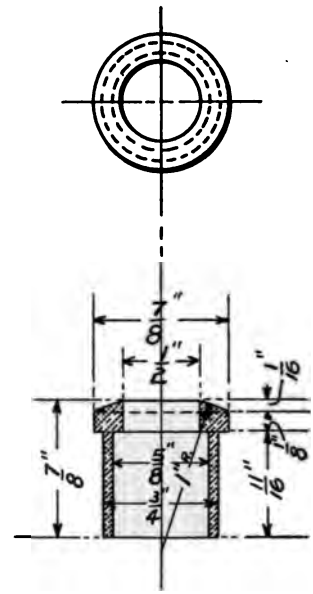


FIG. 3.

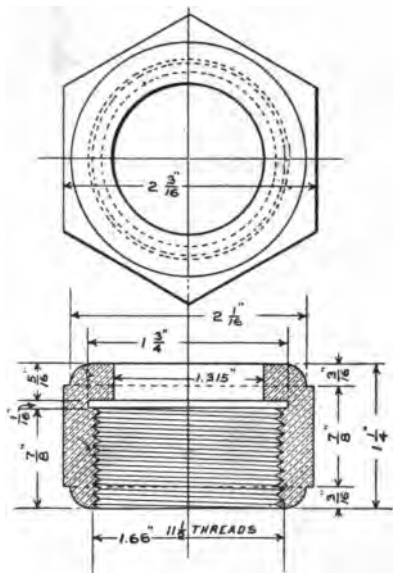


FIG. 4

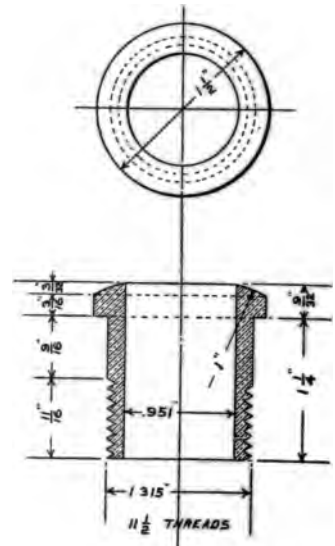


FIG. 5.

The grades are determined by the amount of silicon, in accordance with the attached schedule:

Grade No. 1, silicon	3.00 to 2.50 per cent.
Grade No. 2, silicon	2.50 to 2.00 per cent.
Grade No. 3, silicon	2.00 to 1.50 per cent.
Grade No. 4, silicon	1.50 to 1.00 per cent.

Each carload, or its equivalent, shall be considered as a unit. At least one pig shall be selected at random for each four tons of every carload and so as to fairly represent it.

Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

In case of disagreement between buyer and seller, an independent analyst, to be mutually agreed upon, shall be engaged to sample and analyze the iron. In this event one pig shall be taken to represent every two tons.

The cost of this sampling and analysis shall be borne by the buyer if the shipment is proved up to specifications, and by the seller if otherwise.

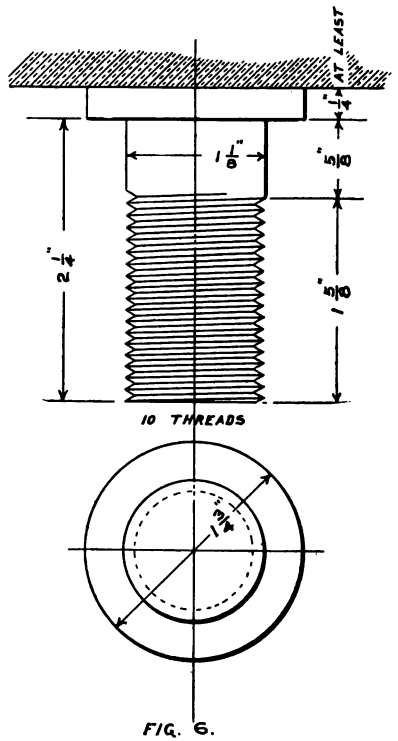


FIG. 6.

SPECIFICATIONS FOR LOCOMOTIVE CYLINDER CASTINGS, CYLINDER BUSHINGS, CYLINDER HEADS, STEAM CHESTS, VALVE BUSHINGS AND PACKING RINGS.

The material used in such castings must conform to the following specifications:

Silicon	1.25 to 1.60 per cent.
Phosphorus	.50 to .80 per cent.
Sulphur	.06 to .10 per cent.
Manganese	.30 to .60 per cent.
Combined carbon	.50 to .70 per cent.
Graphite carbon	2.75 to 3.25 per cent.

Tensile strength, 25,000 lbs. per sq. inch minimum.

Transverse strength, 3,000 lbs. minimum on 1¼-inch round bar, 12 inches between supports.

Deflection, .10 inch minimum on transverse test.

Shrinkage, ⅛ inch in 1 foot as a maximum.

The quality of the iron going into castings under specification shall be determined by means of the "arbitration bar." This is a bar 1¼ inches in diameter and 15 inches long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for it may be made from any of the broken pieces of the transverse test. The expense of the tensile test shall fall on the purchaser.

The tensile test piece should be prepared with threaded ends, 1¼ inches in diameter, and with a central neck 0.8 inch diameter, 1 inch between shoulders, with a 7-32-inch radius at the shoulders, the shoulders being 1 inch in diameter and ¼ inch in length to the thread, the total length of piece being about 3½ inches.

Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds 20 tons an additional set of two bars shall be cast for each 20 tons or fraction thereof above this amount. In case of a change of mixture during the heat one set of two bars shall also be cast for every mixture other than the regular one. Each set of bars is to go in a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

The transverse test shall be made on all the bars cast with supports 12 inches apart, load applied at the middle, and deflection at rupture noted. One bar of every two of each set made must fulfil the requirements to permit acceptance of the castings represented.

The bars shall be molded two in a flask and cast on end; the bottom of the bar being 1-16 inch smaller in diameter than the top, to allow for draft. Pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well

mixed and put through a No. 8 sieve with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 inch.

Borings from the broken pieces of the arbitration bar shall be used for the chemical determinations. One determination for each mold shall be required.

For cylinder heads, steam chests and packing rings the silicon must run between 1.60 and 1.80 per cent, the other elements remaining as above. If cylinder castings are to be bushed from the start and also have valve bushings or false valve seats, they should be made of this latter grade of iron.

B. Do you favor the adoption of the proposed specifications for Foundry Pig Iron?

C. Do you favor the adoption of the proposed specifications for cylinder castings, cylinder bushings, cylinder heads, steam chests, valve bushings and packing rings?

JOS. W. TAYLOR,
Secretary.

LETTER BALLOT VOTE.

A. Fittings for Lubricators. .....

B. Foundry Pig Iron, Specifications for. .....

C. Cylinder Castings, etc., Specifications for. .....

(Name).....

(Title and Road).....

(Address).....

RESULT OF LETTER BALLOT.

CHICAGO, ILL., SEPT. 4, 1906.

DEAR SIR,—The letter ballot which closed August 31, 1906, resulted as follows:

SUBJECTS.	Affirmative.	Negative.	Total.	Votes Necessary.	Result.
A. Fittings for Lubricators	120	21	141	94	Adopted.
B. Specifications for Foundry Pig Iron	125	11	136	91	"
C. Specifications for Cylinder Castings, etc.	125	11	136	91	"

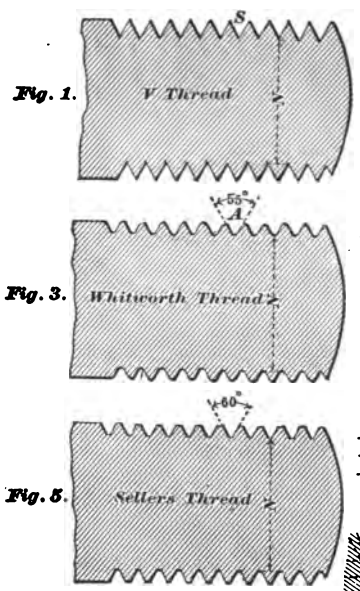
JOS. W. TAYLOR,

Secretary.

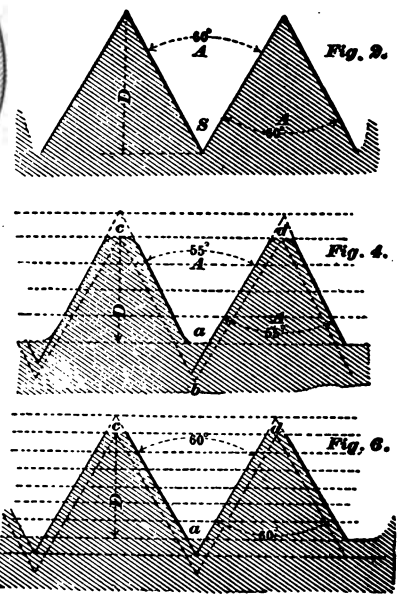
STANDARDS ADOPTED BY THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION.

SCREW THREADS, BOLT HEADS AND NUTS.

At the convention of 1870 the report of a committee recommending the United States Standard Screw Thread was adopted. The forms and dimensions of the threads are shown below:



SCREW THREADS.



SELLERS' STANDARD.

Mr. Sellers, who proposed this system of screw threads, described it in an essay read before the Franklin Institute of Philadelphia, April 21, 1864, as follows:

"The proportions for the proposed thread and its comparative relation to the sharp and rounded threads, will be readily understood from the accompanying diagram in which Figs. 1 and 2 — the latter on an exaggerated scale — represent a sharp thread, Figs. 3 and 4 a rounded top and bottom to the English proportion, and Figs. 5 and 6 the flat top and bottom, all of the same pitch. The angle of the proposed thread is fixed at sixty degrees, the same as the sharp thread, it being more readily obtained than fifty-five degrees; and more in accordance with the general practice in this country. Divide the pitch, or, which is the same thing, the side of the thread into eight equal parts, take off one part from the top and fill in one part in the bottom of the thread, then the flat top and bottom will equal one-eighth of the pitch; the wearing surface will be three-quarters of the pitch, and the diameter of screw at bottom of the thread will be expressed by the formula:

$$\textit{Diameter} - \frac{1{,}299}{\textit{number of threads per inch.}}$$

At the convention of 1892 the Association adopted as standard the United States standard sizes of nuts and bolt heads.

At the convention of 1903 the arrangement of these standards was made to conform to the arrangement as adopted by the Master Car Builders' Association.

The accompanying tables are reprinted from Mr. Sellers' essay. They give the proportions of his standard screw threads, nuts and bolt heads.

PROPORTIONS FOR SELLERS' STANDARD SCREW-THREADS, NUTS AND BOLTS.

Screw-Threads.				Nuts.				Bolt Heads.			
Diameter of screw.	Threads per inch.	Diameter at root of thread.	Width of flat.	Short diameter rough.	Short diameter finish.	Thickness rough.	Thickness finish.	Short diameter rough.	Short diameter finish.	Thickness rough.	Thickness finish.
$\frac{1}{4}$	20	.185	.0062	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{3}{16}$
$\frac{5}{16}$	18	.240	.0074	$\frac{19}{32}$	$\frac{17}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{19}{32}$	$\frac{17}{32}$	$\frac{19}{32}$	$\frac{1}{4}$
$\frac{3}{8}$	16	.294	.0078	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{5}{16}$
$\frac{7}{16}$	14	.344	.0089	$\frac{25}{32}$	$\frac{23}{32}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{25}{32}$	$\frac{23}{32}$	$\frac{25}{32}$	$\frac{3}{8}$
$\frac{1}{2}$	13	.400	.0096	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{7}{16}$
$\frac{9}{16}$	12	.454	.0104	$\frac{31}{32}$	$\frac{29}{32}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{31}{32}$	$\frac{29}{32}$	$\frac{31}{32}$	$\frac{1}{2}$
$\frac{5}{8}$	11	.507	.0113	$1\frac{1}{16}$	1	$\frac{5}{8}$	$\frac{9}{16}$	$1\frac{1}{16}$	1	$1\frac{1}{32}$	$\frac{9}{16}$
$\frac{3}{4}$	10	.620	.0125	$1\frac{1}{4}$	$1\frac{3}{16}$	$\frac{3}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$1\frac{3}{16}$	$\frac{3}{4}$	$\frac{11}{16}$
$\frac{7}{8}$	9	.731	.0138	$1\frac{7}{16}$	$1\frac{3}{8}$	$\frac{7}{8}$	$\frac{13}{16}$	$1\frac{7}{16}$	$1\frac{3}{8}$	$\frac{29}{32}$	$\frac{13}{16}$
1	8	.887	.0156	$1\frac{5}{8}$	$1\frac{9}{16}$	1	$\frac{15}{16}$	$1\frac{5}{8}$	$1\frac{9}{16}$	$1\frac{1}{16}$	$\frac{15}{16}$
$1\frac{1}{8}$	7	.940	.0178	$1\frac{13}{16}$	$1\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{16}$	$1\frac{13}{16}$	$1\frac{3}{4}$	$\frac{29}{32}$	$1\frac{1}{16}$
$1\frac{1}{4}$	7	1.065	.0178	2	$1\frac{15}{16}$	$1\frac{1}{4}$	$1\frac{1}{16}$	2	$1\frac{15}{16}$	1	$1\frac{1}{16}$
$1\frac{3}{8}$	6	1.160	.0208	$2\frac{3}{16}$	$2\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{5}{16}$	$2\frac{3}{16}$	$2\frac{1}{8}$	$1\frac{3}{32}$	$1\frac{5}{16}$
$1\frac{1}{2}$	6	1.284	.0208	$2\frac{3}{8}$	$2\frac{5}{16}$	$1\frac{1}{2}$	$1\frac{7}{16}$	$2\frac{3}{8}$	$2\frac{5}{16}$	$1\frac{3}{16}$	$1\frac{7}{16}$
$1\frac{5}{8}$	$5\frac{1}{2}$	1.389	.0227	$2\frac{9}{16}$	$2\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{9}{16}$	$2\frac{9}{16}$	$2\frac{1}{2}$	$1\frac{9}{32}$	$1\frac{9}{16}$
$1\frac{3}{4}$	5	1.491	.0250	$2\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{3}{4}$	$1\frac{11}{16}$	$2\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{3}{8}$	$1\frac{11}{16}$
$1\frac{7}{8}$	5	1.616	.0250	$2\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{7}{8}$	$1\frac{13}{16}$	$2\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{15}{32}$	$1\frac{13}{16}$
2	$4\frac{1}{2}$	1.712	.0277	$3\frac{1}{8}$	$3\frac{1}{16}$	2	$1\frac{15}{16}$	$3\frac{1}{8}$	$3\frac{1}{16}$	$1\frac{9}{16}$	$1\frac{15}{16}$

PROPORTIONS FOR SELLERS' STANDARD NUTS AND BOLTS.

Rough Nut = one and one-half diameter of bolt + $\frac{1}{8}$.

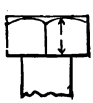
Finished Nut = one and one-half diameter of bolt + $\frac{1}{16}$.

Rough Nut = diameter of bolt.

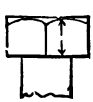
Finished Nut = diameter of bolt—$\frac{1}{16}$.

Rough Head = one and one-half diameter of bolt + $\frac{1}{8}$.

Finished Head = one and one-half diameter of bolt + $\frac{1}{16}$.



Rough Head = one-half distance between parallel sides of head.



Finished Head = diameter of bolt—$\frac{1}{16}$.

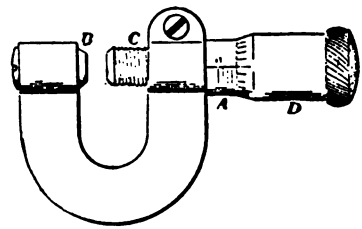
SQUARE BOLT HEADS.

In 1899 the following dimensions for square bolt heads were adopted as standard:

The side of the head shall be one and one-half times the diameter of the bolt, and the thickness of the head shall be one-half the side of the head.

SHEET METAL GAUGE.

At the convention of 1882 the Brown & Sharpe micrometer gauge shown below was adopted as standard for the measurement of sheet metal (see page 132, report 1882). Reaffirmed 1891 (see pages 160, 161, report 1891).



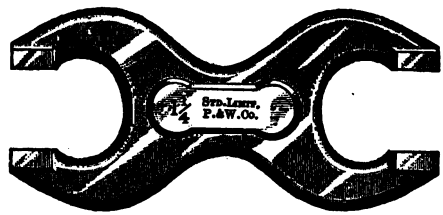
DISTANCE BETWEEN BACKS OF FLANGES.

At the convention of 1884 a motion prevailed that the standard distance between the backs of tires for tender locomotive truck and driving wheels be not less than 4 feet 5⅛ inches, nor more than 4 feet 5½ inches. (See page 26, report 1884.) Modified in 1903. See report of Committee on Revision of Standards.

LIMIT GAUGES FOR ROUND IRON.

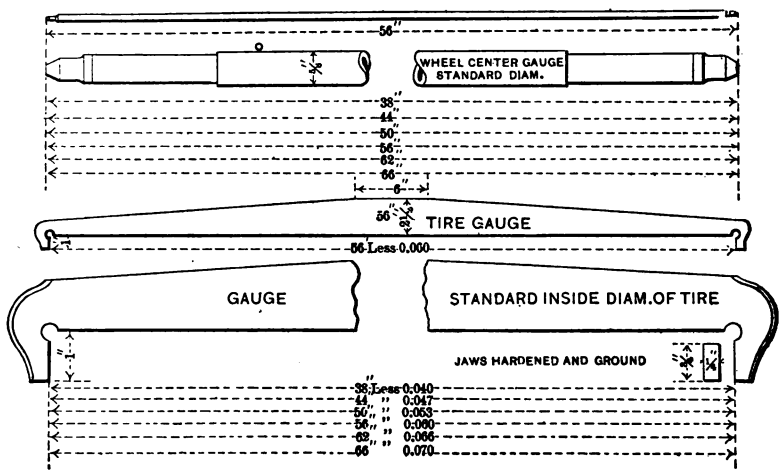
At the convention of 1884 the Pratt & Whitney limit gauges for round iron, shown below, were adopted as standard. (See page 168, report 1884.) Reaffirmed 1891 (see pages 160, 161, report 1891).

Nominal Diameter. Of Iron. Inches.	Large Size, End. Inches.	Small Size, End. Inches.	Total Variation. Inches.
1/4	.2550	.2450	.010
5/16	.3180	.3070	.011
3/8	.3810	.3690	.012
7/16	.4440	.4310	.013
1/2	.5070	.4930	.014
9/16	.5700	.5550	.015
5/8	.6330	.6170	.016
3/4	.7585	.7415	.017
7/8	.8840	.8660	.018
1	1.0095	.9905	.019
1 1/8	1.1350	1.1150	.020
1 1/4	1.2605	1.2395	.021



DRIVING WHEEL CENTERS AND SIZES OF TIRES.

At the convention of 1886 the report of a committee was adopted which recommended driving-wheel centers to be made 38, 44, 50, 56, 62 or 66 inches diameter. At the Twentieth Annual Convention the recommendations of a committee were adopted, making tire gauges manufactured by Messrs. Pratt & Whitney, Hartford, Connecticut, and here illustrated, standards of the Association. The sizes and the allowance for shrinkage are as follows:



At the Twenty-sixth Annual Convention the following sizes were adopted as standards for large driving wheels: 70, 74, 78, 82, 86 and 90 inches.

Reaffirmed in 1891 (see pages 160, 161, report 1891).

SECTION OF TIRE.

At the convention of 1893 the standard forms of tires shown on Plate 1 were adopted as standard. Railroad companies ordering tires will save time by specifying these forms.

At the convention of 1896 a minimum thickness of 1 inch for the flanges of engine and truck wheels was adopted as standard practice; determination to be made by M. C. B. flange thickness gauge. (See Proceedings for 1896.)

BOILER AND FIRE-BOX STEEL SPECIFICATIONS.

Adopted in 1894. (See pages 68-92, report 1894.) Revised June, 1904.

SPECIFICATION FOR BOILER AND FIRE-BOX STEEL.

MADE BY THE OPEN HEARTH PROCESS.

1. SPECIAL REQUIREMENTS FOR SHELL SHEETS.

This grade of steel is known to the trade as flange or boiler steel. The desired tensile strength is 60,000 pounds per square inch, with minimum and maximum limits 55,000 and 65,000 pounds. The elongation in eight inches shall not be less than twenty-five per cent for sheets three-quarters of an inch thick or under. For thicker sheets, deduct one per cent from specified elongation for each one-eighth inch additional thickness.

2. CHEMICAL REQUIREMENTS FOR SHELL SHEETS.

	Per cent.
Phosphorus shall not exceed (acid)	0.06
Phosphorus shall not exceed (basic)	0.04
Sulphur shall not exceed	0.05
Manganese	0.30 to 0.60

3. SPECIAL REQUIREMENTS FOR FIRE-BOX STEEL.

The desired tensile strength is 57,000 pounds per square inch, with minimum and maximum limits 52,000 and 62,000 pounds. The elongation in eight inches shall not be less than twenty-six per cent.

4. CHEMICAL REQUIREMENTS FOR FIRE-BOX SHEETS.

	Per cent.
Carbon	0.15 to 0.25
Phosphorus shall not exceed (acid)	0.04
Phosphorus shall not exceed (basic)	0.03
Sulphur shall not exceed	0.04
Manganese	0.30 to 0.50

GENERAL REQUIREMENTS.

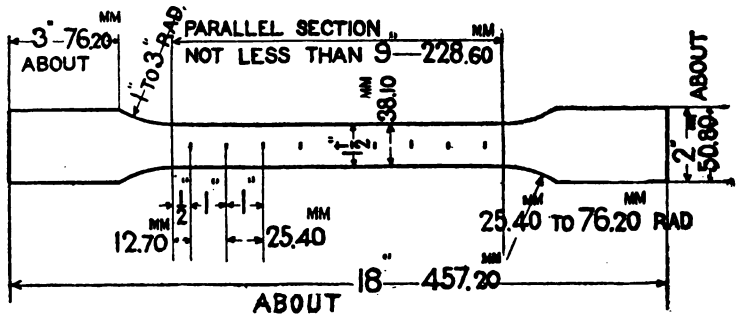
5. BENDING TESTS.

Test specimens for this purpose shall be 1½ inches wide, and for material ¾ inch or less in thickness shall be of the same thickness as that of the finished sheet. For sheets more than ¾ inch thick, the bending-test specimen may be ½ inch thick. The sheared edges of bending-test

specimens may be milled or planed. The cold bending test shall be made on the material in the condition in which it is to be used. The specimen for quench bending test shall be heated to a light cherry red, as seen in the dark, and quenched in water having a temperature between 80° and 90° F. Boiler steel and fire-box steel, before and after quenching, shall bend cold 180° flat on itself without fracture on the outside of the bent portion. The bending test may be made by pressure or by blows. One cold bending specimen and one quenched bending specimen will be furnished from each plate as it is rolled. The homogeneity tests for fire-box steel shall be made on one of the broken tensile test specimens.

6. SPECIMENS FOR TENSILE TEST.

Two tensile test specimens will be furnished from each plate as it is rolled. The standard test specimen of 8-inch gauged length shall be used for the tensile test. The standard shape of the test specimens shall be as shown by the following sketch:



PIECE TO BE OF SAME THICKNESS AS THE PLATE.

7. HOMOGENEITY TEST.

The homogeneity test for fire-box steel is made as follows: A portion of the broken tensile test specimen is either nicked with a chisel or grooved on a machine, transversely about a sixteenth of an inch deep, in three places about two inches apart. The first groove should be made on one side, two inches from the square end of the specimen; the second, two inches from it on the opposite side, and the third, two inches from the last and on the opposite side from it. The test specimen is then put in a vise, with the first groove about a quarter of an inch above the jaws, care being taken to hold it firmly. The projecting end of the test specimen is then broken off by means of a hammer, a number of light blows being used, and the bending being away from the groove. The specimen is broken at the other two grooves in the same way. The object of this

treatment is to open and render visible to the eye any seams due to failure to weld up, or to foreign interposed matter, or cavities due to gas bubbles in the ingot. After rupture, one side of each fracture is examined, a pocket lens being used if necessary, and the length of the seams and cavities is determined. The broken specimen shall not show any single seam or cavity more than ¼ inch long in either of the three fractures.

8. VARIATION IN WEIGHT.

The variation in cross section or weight of more than two and one-half per cent from that specified will be sufficient cause for rejection, except in the case of sheared plates, which will be covered by the following permissible variations:

Plates 12½ pounds per square foot or heavier, up to 100 inches wide, when ordered to weight, shall not average more than 2½ per cent variation above or 2½ per cent below the theoretical weight. When 100 inches wide and over five per cent above or five per cent below the theoretical weight.

Plates under 12½ pounds per square foot, when ordered to weight, shall not average a greater variation than the following:

Up to 75 inches wide, 2½ per cent above or 2½ per cent below the theoretical weight. Seventy-five inches wide up to 100 inches wide, five per cent above or three per cent below the theoretical weight. When 100 inches wide and over, ten per cent above or three per cent below the theoretical weight.

For all plates ordered to gauge there will be permitted an average excess of weight over that corresponding to the dimensions on the order equal in amount to that specified in the following table:

9. TABLE OF ALLOWANCES FOR OVERWEIGHT FOR RECTANGULAR PLATES WHEN ORDERED TO GAUGE.

Plates will be considered up to gauge if measuring not over 1-100 inch less than the ordered gauge.

The weight of 1 cubic inch of rolled steel is assumed to be 0.2833 pound.

PLATES ¼ INCH AND OVER IN THICKNESS.

Thickness of plate	Width of plate. Up to 75 inches.	75 to 100 inches.	Over 100 inches.	Over 115 inches.
Inch.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
1/4	10	14	18	....
5/16	8	12	16	....
3/8	7	10	13	17
7/16	6	8	10	13
1/2	5	7	9	12
9/16	4 1/2	6 1/2	8 1/2	11
5/8	4	6	8	10
Over 5/8	3 1/2	5	6 1/2	9

PLATES UNDER ¼ INCH IN THICKNESS.

Thickness of plate. Inch.	Width of plate. Up to 50 inches. Per cent	50 inches and above. Per cent.
1/8 up to 5/32	10	15
5/32 " 3/16	8 1/2	12 1/2
3/16 " 1/4	7	10

10. BRANDING.

Each sheet shall be stamped with the melt number and maker's name, and the test specimens cut from it shall be stamped with separate identifying marks or numbers, as may be specified by the purchaser.

11. INSPECTION.

The inspector, representing the purchaser, shall have all reasonable facilities afforded to him by the manufacturer to satisfy him that the finished material is furnished in accordance with these specifications.

STANDARD METHOD OF CONDUCTING EFFICIENCY TESTS OF LOCOMOTIVES.

In 1894 a method of conducting tests of locomotives was submitted by a committee of the Association, and on motion adopted as a standard of the Association. (See page 200, report 1894.)

The tests are as follows:

*A. Preparations for Test and Location of Instruments.**

1. The locomotive should be put in good condition preparatory to the test. The boiler and tubes should be tight, and both the interior and exterior surfaces should be clean, and, if possible, free from scale. There should be no lost motion in the valve gear, and the valves should be set properly. No change in the engines should be allowed during the progress of a series of tests, unless so ordered for the purposes of the trial.

A glass water-gauge should be fitted to the boiler, if not already provided, and side of it there should be a graduated scale to assist in correcting water quantities, caused by change of inclination of the boiler, and difference of levels when beginning and ending a test. The notches on the quadrant should be marked by large figures, so that they can be read by the cab assistant. The throttle valve lever should be provided with a scale so as to show the degree of opening of the throttle valve.

The point of cut-off of the valves should be determined for each notch in the quadrant.†

* The directions here given apply largely to both shop and road tests, but especially the latter.

† See appendix for description of valve diagram apparatus used on Norfolk & Western Railway.

2. The valves and pistons should be tested for leakage with the engine at rest. The steam valve can be tried by setting the engine so that the valve on one side will be at the center of its throw, in which position both ports are usually covered, and pulling open the throttle valve, blocking the drivers if there is a tendency for the engine to be set in motion. Leakage of the valve, if any occurs, will show itself by escaping at the open cylinder cocks. The tightness of the piston may be tested by setting the engine so that it makes steam, blocking the drivers and opening the throttle valve. This should be tried first on one cylinder and then on the other, and, if desired, it may be tried with the pistons at various points in the stroke. The leakage, if any occurs, will be shown at the open cylinder cock.

3. The following instruments should be verified or calibrated: Steam gauges, draft gauge, pyrometer, thermometers for calorimeter and feed-water, water meter, tank, revolution counter, indicator springs, dynamometer springs and dynamometer recording mechanism. The radiation loss on the steam calorimeter should be determined, or the normal readings ascertained,* and the quantity of steam which passes through the instrument in a given time should be measured.

4. The quantities of steam used by the various auxiliaries of the locomotive can be determined by noting the change in weight of the engine standing upon scales while they are each in use under the usual conditions for known times. Similarly leakage of water and steam can be determined. The quantities can then be properly deducted from the total water used.

5. To facilitate the measurement of coal and the determination of the quantity used during any desired period of the run, it is desirable to provide a sufficient number of sacks of a size holding a weight of, say, 100 pounds, and weigh the coal into these sacks preparatory to starting on the test. If desired, the sacks may be numbered to facilitate the accuracy of record.

6. The instruments and other apparatus that should be provided and their locations are as follows:

To facilitate the work of operating the indicators and reading the instruments at the front end, the smoke-box should be surrounded with a wooden fence, or "pilot-box," as it may be called, resting on the top of the cow-catcher, and extending back far enough to inclose also the sides of the cylinders. This box is floored over above the cylinder heads, and the inclosure thus provided forms a convenient place for the accommodation of the assistants at this end of the locomotive, and it affords them some measure of protection against wind and rain, as also the joltings and vibrations due to rapid travel.

A special steam-gauge with a long siphon is to be used for registering the boiler pressure. It can best be located on the left-hand side of the cab.

The indicator apparatus which is most suitable consists of a three-way cock for the attachment of the indicators, and some form of pantagraph

or other correct reducing motion for the driving rig. The pipes leading from the cock to the cylinder should be ¾ inch diameter inside, and they should connect into the side of the cylinder rather than into the two heads. The indicator should also be piped so that a steam-chest diagram can be drawn by it, and from this the steam-chest pressure determined. Sharp bends in the pipe should be avoided, and they should be well covered, to intercept radiation. The three-way cock should be provided with a clamp rigidly secured to the cylinder, and thus overcome any tendency of the indicators to move longitudinally with reference to the driving rig. Absolute rigidity is highly essential in this particular. Two forms of pantagraph motion are shown in Figs. 1 and 2. In both of these the reduced motion is transmitted to the indicator through a light rod, working horizontally. By this means a cord eight or ten inches in length is sufficient for connection to the indicator. Care should be taken to set the instrument in such a position that the cord pin in the end of the rod travels in a direction pointing to the groove in the paper drum. Pantagraph motions arranged as noted are preferable to the common pendulum and quadrant reducing mechanism, with its long stretch of cord. For another type of correct reducing motion see appendix.

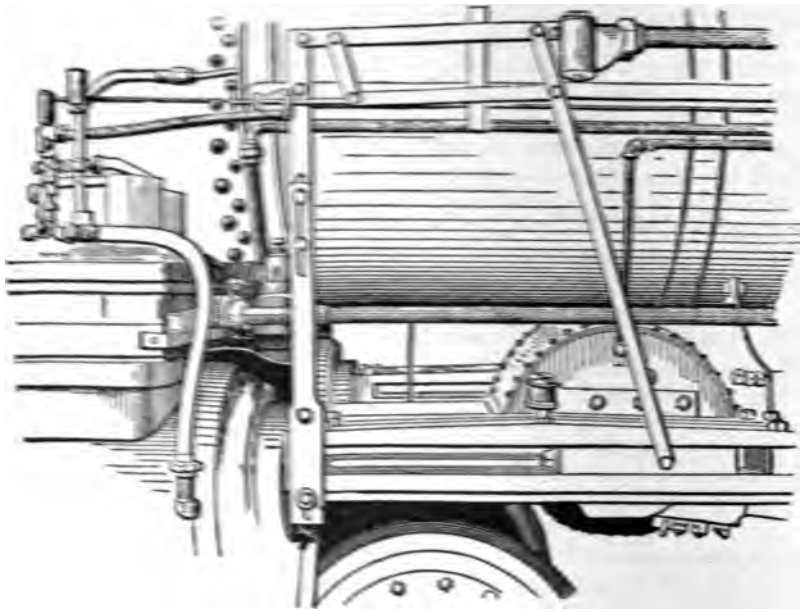
A draught gauge consisting of a U tube containing water, properly graduated in inches, should be placed in the cab and connected to the smoke-box by a ⅜-inch pipe. This long pipe steadies the water, and the readings can be taken by the cab assistant.

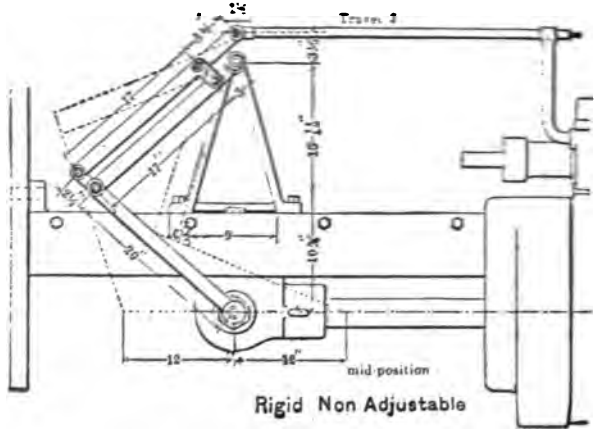
A pyrometer for showing the temperature of the escaping gases should be used in a position below the tip of the exhaust nozzles.

The calorimeter should be attached either to the steam dome at a point close to the throttle opening or to the steam passages in the saddle casting on one side, according as it is desired to obtain the character of the steam at one point or the other. The former location is preferred by the committee. A perforated ½-inch pipe should be used for sampling and conveying the steam to the calorimeter pipe. For descriptions of various forms of calorimeters which are adapted to locomotive use, see Trans. A. S. M. E., Vol. X, page 327; Vol. XI, page 790; Vol. XII, page 823.

The water meter should be attached to the suction pipe of the injector, and located at a point where it can be conveniently read when the locomotive is running. It should be provided with a check valve to prevent hot water from flowing back to it from the injector and a strainer to intercept foreign material.

To measure the depth of the water in the tank a metallic float should be used carrying a vertical tube which slides upon a graduated rod, the lower end of which rests upon the bottom of the tank. This should be placed at the center of gravity of the water space. If the desired location can not be used, provision should be made for ascertaining the level or inclination of the tank. The best device for this purpose is a plumb line of a certain known length, provided at the bottom with a double horizon-





Rigid Non Adjustable

tal scale having one set of divisions parallel to the side of the tank and the other set at right angles to it. From the readings on these scales referred to, the length of the line, the level of the tank in both directions can be ascertained. A similar device should be attached to the boiler to correct for the variation of its inclination.* The plumb line may be conveniently attached for this purpose at some point near the front end.

The revolution counter should be placed near the front end of the engine, in plain view of the pilot-box. It is operated through a belt from the driver axle. This recommendation applies to that form of counter which shows at a glance the exact speed in revolutions per minute.

A stroke counter should be provided for showing the number of strokes made by the air-pump.

Electric connection should be made between the dynamometer car and cab, so that dynamometer records and indicator diagrams may be taken simultaneously. Another desirable provision is a speaking-tube leading from the dynamometer car to the locomotive cab, and one also to the pilot-box.

7. It is needless, except for a complete record of directions for preparatory work, to call attention to the desirability of having the test, and especially the road test, made under the supervision of a competent person, who is not only familiar with the details of the testing, but also with the proper method of firing and mechanical operation of the locomotive. This is a most important factor, for it is only the clear-headed and able experimenter who is likely to obtain satisfactory work in this most difficult department of engineering tests.

The conductor of the test is best able to determine the number of assistants required, the various duties of the men, and the manner of making records. In general, three (3) men are sufficient to conduct a locomotive test, one (1) being at each cylinder, and one (1) in the cab for taking records.

The men at the cylinders will take indicator diagrams, and one will read the revolution counter and the pyrometer. The indicator papers will be numbered in consecutive order for each cylinder before the test begins, and when the diagram is taken the papers will be deposited through a slot in a box near each assistant.

The cab assistant notes the time of leaving and arriving at stations, the position and time of opening and closing the throttle, the time of taking indicator diagrams, for which he shall determine the time and give the signal by any effective means; the time of blowing off, the time the blower is applied, the number of applications of the injector, the position of the reverse lever, the steam pressure, the draught gauge, the time of passing important stations, the readings of the water glass, meter and air-pump counter, the number of sacks of coal used, the reading of the tank float, the temperature of the feed-water and atmosphere, the direc-

* See appendix for description of special devices used on the Norfolk & Western Railway for this purpose.

tion and force of the wind, the condition of the rail and state of the weather. Many of these readings are as nearly as possible simultaneous with the signal for taking indicator diagrams, and one experienced man in the cab will have no difficulty in entering all of these records in a note-book properly prepared with ruled columns and headings. In case of short stops at stations, one of the men at the indicators can take the tank float observations, or any observation that is advisable at stations. The weights of coal placed upon the tender have been checked by these two persons when weighing it out to the engine. One man takes the level of the boiler at stopping-places where this is required.

When the calorimeter and smoke-box gas samples are used another assistant is required.

In the dynamometer car two (2) men are required, who record the time of each start and stop, the time of passing each station and mile-post, time of taking each indicator diagram as obtained from the signal given by the cab assistant, and all these events are marked on the dynamometer paper. These men, as well as one of the engine assistants, will note the direction and force of the wind, the temperature of the atmosphere and condition of the weather.

8. It is of great importance, after the preparatory work has been accomplished, that a preliminary run be made with the locomotive, in order to fairly test the apparatus and to accustom the men to their duties.

B. The Dynamometer Car.

With a suitable dynamometer car the force required to move the train, or the pull upon the drawbar, is registered upon a strip of paper traveling at a definite rate per mile. The scale upon which this diagram is drawn should be as large as is possible within reasonable limits. A scale of ¼ inch per 1,000 pounds pull is suitable, as the maximum registered pull rarely exceeds 30,000 pounds.

The height of the diagram should be measured from a base line drawn upon the paper by a stationary pen, so located that when no force is exerted upon the drawbar the base line should coincide with zero pull.

The apparatus should be arranged to make a record of time marks in connection with the curve showing the pull. A chronometer should be provided having an electric circuit-breaker, by means of which a mark is made on the dynamometer paper every five (5) seconds. A better apparatus may be used in which a continuous speed curve is traced upon the paper parallel to the curve of pull. The ordinates of this curve, measured from a base line, give the speeds desired.

The location of mile-posts and other points along the route should be fixed upon the dynamometer paper by employing an additional pen, and operating it by means of electric press buttons, which are placed at convenient points in the car.

As already noted, a similar device should be provided for marking upon the dynamometer paper the time of taking indicator diagrams.

The rate of travel of the paper per mile should be such that one inch measured upon the diagrams represents 100 feet for short-distance work, and for long-distance work ½ inch to ¼ inch should be used to represent 100 feet of track. The driving mechanism for the paper should be so arranged that it can be changed to give these three proportions. It is necessary to have all the registering pens located upon the same transverse line at a right angle with the direction of the movement of the paper in order that simultaneous data may be recorded.

C. Method of Conducting the Road Test.

The locomotive having been brought to the train, the steam pressure being at or near the working point, the fire being clean and in good condition, the ash-pan being also clean, observations are taken, say, five (5) minutes before starting time, of the thickness and condition of the fire, the height of water in the boiler, the depth in the tank, the levels, the water meter and the air-pump counter, and thereafter the regular observations are carried forward, and coal is fired from the weighed sacks.

Indicator diagrams should be taken as frequently as possible, the intervals between them being not over two minutes.

Other regular observations should be taken at close intervals. Calorimeter readings, when taken, should be continued for at least five (5) minutes at one minute intervals.

At water stations careful records should be obtained of water heights and levels of boiler and tank.

As the end of the route is approached, the fire should be burned down so as to leave the same amount and the same condition as at the start. When the end is finally reached the fire should be raked and its condition carefully noted. If it differs from that which obtained at the beginning, an estimated allowance must be made for such difference.

At the close of the test the height of water in the boiler should be the same as at the beginning, or, if not, the difference, corrected for inclination of the boiler, should be allowed for.

During the process of weighing the coal into the sacks numerous samples should be obtained and placed in a covered box, and a final sample of these selected. This is to be dried and subjected to chemical analysis and calorimeter test. The sample is weighed before and after drying, and data obtained for determining the weight of dry coal used during the test. The temperature of the feed-water can be best taken at the tank cock, in order to obtain that of a mixed sample.

The duration of the road test is the length of time which the throttle valve is open.

D. The Data and Results.

The data and results of the road test may be tabulated in the form given in Table No. 1. This form corresponds in general with that recommended for shop test, namely, Table No. 2.

TABLE No. 1.

Data and Results of Road Test on....Engine, Made....189 .

General dimensions, etc. (to be accompanied by a complete description of engine with drawings and dimensions, also of train and route):

1. Kind of engine .....
2. Size of cylinders.....
3. Clearance of cylinders .....per cent
4. Area of heating surface .....sq. ft.
5. Area of grate surface.....sq. ft.
6. Size of exhaust nozzles .....inches
7. Average weight of locomotive and tender (including water)....tons
8. Number of cars .....
9. Weight of cars .....tons
10. Length of route .....miles
11. Number of ton-miles of train load .....ton-miles
12. Number of ton-miles of total load.....ton-miles
13. Schedule time of trips.....

Total Quantities.

14. Duration or time throttle valve is open .....hours
15. Weight of dry coal burned .....lbs.
16. Weight of water evaporated, corrected for moisture in the steam and loss at injector*.....lbs.
17. Weight of ashes and refuse taken from ash-pan.....lbs.
18. Weight of cinders from smoke-box .....lbs.
19. Percentage of ash as found by coal calorimeter test.....per cent
20. Total heat of combustion as found by calorimeter test ....B. T. U.
21. Results of chemical analysis of coal .....

Power Data.

22. Mean effective pressure, H. P. cyls.....lbs.
23. Mean effective pressure, L. P. cyls.....lbs.
24. Average revolutions per minute.....rev.
25. Indicated horse-power, H. P. cyls.....H. P.
26. Indicated horse-power, L. P. cyls.....H. P.
27. Indicated horse-power, whole engine.....H. P.
28. Pull on drawbar.....lbs.
29. Dynamometer horse-power .....H. P.

Averages of Observations of Instruments.

30. Average boiler pressure .....lbs.
31. Average steam-chest pressure .....lbs.
32. Average temperature of smoke-box..... °
33. Average drought suction..... "

* Should be corrected for steam used by calorimeter, air pump, blower, safety valve and whistle, to find cylinder results—line 56.

34. Average temperature of feed-water..... °
35. Average temperature of atmosphere..... °
36. Average percentage of moisture in the steam.....per cent
37. Maximum percentage of moisture in the steam.....per cent
38. Weather, wind, etc.....

Other Data.

39. Average position of throttle.....
40. Average position of reversing lever.....
41. Average speed in miles per hour.....
42. Maximum speed in miles per hour.....
43. Number of stops.....
44. Average number of strokes of air pump per minute.....
45. Total estimated weight of steam used by air pump per hour.....lbs.
46. Estimated loss of steam at safety valve per hour.....lbs.
47. Estimated loss of steam at whistle per hour.....lbs.
48. Estimated weight of steam used by blower per hour.....lbs.
49. Estimated loss of steam at calorimeter per hour.....lbs.

Hourly Quantities.

50. Weight of dry coal burned per hour.....lbs.
51. Weight of dry coal burned per hour per square foot of grate surface .....lbs.
52. Weight of coal burned per square foot of heating surface.....lbs.
53. Weight of water evaporated per hour.....lbs.
54. Equivalent weight of water evaporated per hour with feed-water at 100° and pressure 70 lbs.....lbs.
55. Equivalent weight of water from 100° at 70 lbs. evaporated per square foot of heating surface.....lbs.
56. Weight of water consumed by engine cylinder (line 53, less sum of lines 45, 46, 47, 48 and 49).....lbs.

Principal Results — Complete Engine and Boiler.

57. Coal consumed per I. H. P. per hour.....lbs.
58. Coal consumed per dynamometer horse-power per hour.....lbs.
59. Coal consumed per ton-mile of train load.....lbs.
60. Coal consumed per ton-mile of total load.....lbs.
61. Weight of standard coal consumed per I. H. P. per hour.....lbs.
62. Weight of standard coal consumed per dynamometer horse-power per hour.....lbs.
63. Weight of standard coal consumed per ton-mile of train load....lbs.
64. Weight of standard coal consumed per ton-mile of total load.....lbs.

Boiler Results.

65. Water evaporated per pound of coal .....lbs.
66. Equivalent evaporation per pound of coal from and at 212°.....lbs.

67. Equivalent evaporation per pound of combustible from and at 212° .....lbs.
68. Heat imparted to each pound of steam used from average temperature of feed at average steam pressure in British thermal units.....

Cylinder Data.

69. Mean initial pressure above atmosphere.....lbs.

		H. P. Cyl.	L. P. Cyl.
70.	Cut-off pressure above zero.....lbs.	.....	.....
71.	Release pressure above zero .....lbs.	.....	.....
72.	Compression pressure above zero.....lbs.	.....	.....
73.	Lowest back pressure above or below atmosphere .....lbs.	.....	.....
74.	Proportion of forward stroke completed at cut-off	.....	.....
75.	Proportion of forward stroke completed at release	.....	.....
76.	Proportion of return stroke uncompleted at compression	.....	.....
77.	Mean effective pressure (lines 22 and 23) lbs.	.....	.....

Cylinder Results.

78. Total water consumed per indicated horse-power per hour, corrected for moisture in steam.....lbs.
79. Water consumed per I. H. P. per hour by cylinders alone (from line 56).....lbs.

		H. P. Cyl.	L. P. Cyl.
80.	Steam accounted for by indicators at cut-off.lbs.	.....	.....
81.	Steam accounted for by indicator at release.lbs.	.....	.....
82.	Proportion of feed-water used by cylinders (line 79) accounted for at cut-off.....	.....	.....
83.	Proportion of feed-water used by cylinders accounted for at release.....	.....	.....
84.	Total heat supplied by boiler to cylinders per hour in British thermal units.....	.....	.....
85.	Total heat supplied by boiler to cylinders per minute per indicated horse-power in British thermal units.....	.....	.....
86.	Total heat supplied by boiler to cylinders per minute per dynamometer horse-power in British thermal units	.....	.....

The following form for the tabulation of the results of locomotive tests will be found convenient. They can, of course, be modified to suit any method of testing, whether standard or not:

LOCOMOTIVE TESTS — GENERAL RESULTS.

.....*Railroad Co.*
.....*Tests of Locomotive No.....*, *between*.....
and.....*Distance*.....*Miles. Train No*.....
.....*Bound.* ....., *18*....
Kind of Coal..... *Coal Analysis*.....
Calorimetric Value of Coal.....

Trip No.....
Date .....
Left .....at.....
Arrived .....at.....
Left .....at.....
Arrived .....at.....

1. Weather .....
2. Mean temperature of atmosphere.....
3. Direction of wind.....
4. Velocity of wind, miles per hour.....
5. Condition of rails.....
6. Weight of train in tons of 2,000 lbs., including locomotive, tender, passengers and freight.....
7. Weight of train in tons of 2,000 lbs., excluding the locomotive and tender .....
8. Equivalent number of standard cars at .....tons each.....
9. Size of exhaust nozzle, single or double.....
10. Maximum boiler pressure by gauge.....
11. Minimum " " " " .....
12. Average " " " " ....
13. Prevailing position of throttle (wide open = 1.00).....
14. " " " reverse lever (notch) .....
15. " points of cut-off .....
16. Schedule time in motion.....
17. Actual " " " .....
18. Time made up in minutes.....
19. Aggregate intermediate stops, minutes.....
20. Time during which power was developed, or throttle open.....
21. Maximum number of revolutions per minute.....
22. Minimum number of seconds per mile.....
23. Maximum rate of speed, miles per hour.....
24. Average speed, miles per hour.....
25. Actual weight of coal fired.....

26. Moisture in coal, percentage.....
27. Dry coal fired.....
28. Actual weight of wood used.....
29. Total weight of coal fired (wood added at .4).....
30. Weight of refuse in fire-box and ash-pan.....
31. " unconsumed coal recovered from fire-box and ash-pan.....
32. Total weight of coal consumed (Item 29-31).....
33. Net weight of ashes in fire-box and ash-pan.....
34. Weight of cinders (sparks) in smoke-box.....
35. Percentage of ash in coal.....
36. " " cinders (sparks).....
37. " " total refuse.....
38. Percentage of combustible consumed.....
39. Weight of combustible utilized.....
40. Number of miles run per ton (2,000 lbs.) of coal.....
41. " " pounds of coal used per mile.....
42. Coal used per ton of train per 100 miles.....
43. " " " car-mile.....
44. Average weight of coal burned per square foot of grate surface per hour .....
45. Total coal per indicated horse-power developed per hour.....
46. Average temperature of feed-water.....
47. Weight of water drawn from tender.....
48. Waste of injector, leakage, etc.....
49. Weight of water apparently evaporated (Item 47-48).....
50. Percentage of moisture in steam.....
51. Water actually evaporated, corrected for quality of steam.....
52. Actual evaporation per pound of total coal.....
53. Equivalent evaporation from and at 212° per pound of coal.....
54. " " " " " " " " " combustible.
55. Water used per ton of train per 100 miles.....
56. " " " car-mile .....
57. " " " hour while developing power.....
58. " " " indicated horse-power per hour.....
59. " " " sq. ft. of heating surface, from and at 212°.....
60. " " " " " " grate " " " " .....
61. Maximum indicated horse-power developed.....
62. Average " " " .....
63. Dry steam used per indicated horse-power, per hour, per indicator diagram .....
64. Average number of sq. ft. of heating surface per indicated horse-power
65. Average number of indicated horse-power per sq. ft. of grate surface.
66. Prevailing temperature in smoke-box while using steam.....
67. " draft in smoke-box while using steam, in inches of water.

SHOP TEST.

A. Preparation and Location of Instruments.

In preparing for a shop test the preparations described for the road test should be followed so far as the nature of the test requires. When run as a stationary engine the locomotive is not circumscribed by the conditions of road service, and many provisions required on the road are unnecessary. It is unnecessary to determine the quantity of steam consumed by the air pump and auxiliaries, for these are not brought into use on the shop test; and no occasion exists for finding the quantity lost at the safety valve, for on the continuous shop run the steam pressure can be maintained at a uniform point, and blowing off readily prevented. It is unnecessary to use sacks for the convenient measure of coal, because the coal can be readily weighed up in lots as fast as needed for the test. It is unnecessary to provide a "pilot-box," and no fixed location of the instruments is required, as on the road test. The feed-water may be weighed before it is supplied to the tank, and the tank may be used in this case as a reservoir, the float showing its depth. The meter would thus be unnecessary as the principal instrument of measurement, but a meter is in all cases useful as a check upon this most important element in the data. The long indicator pipes required on the road test may be dispensed with, and one indicator applied close to each end of the cylinder, a practice much to be preferred to the use of a three-way cock and the single indicator. The dynamometer car is not required, but its equivalent should be provided, consisting of a dynamometer which registers the pull on the drawbar in the same manner as the device used on the road.

The number of assistants required on a shop test is less than that needed for a road test. A good test can be made with four (4) assistants, distributed as follows:

One assistant for operating indicators.

One assistant for measuring water.

Two (2) assistants for general observations and coal measurement.

B. Conditions of Test.

The test should be continued for a run of at least two (2) hours from the time normal conditions have been established.

At the close of the test the water height in the boiler and the height of water in the tank should be the same as at the beginning, or proper corrections made for any differences which may exist.

The fire-box and ash-pit are then cleaned, and such unburnt coal as may be contained in the refuse is separated, weighed and deducted from the total weight of coal fired. The balance of the refuse is weighed, as also the cinders removed from the smoke-box.

During the progress of the test samples of the various charges of coal should be obtained, and at its close a final sample of these should be selected, dried and subjected to chemical analysis and calorimeter test.

The weight of the sample as taken before and after drying to ascertain the weight of moisture contained in the fuel.

C. The Data and Results.

The data and results of the shop test can best be arranged in the manner indicated in Table No. 2. So far as these are in common with the data and results obtained on the road test, the forms used on both kinds of test are identical.

TABLE No. 2.

*Data and Results of Shop Test on....Engine, made.....*189.....

General dimensions, etc. (to be accompanied by a complete description, with drawings and full dimensions).

1. Kind of engine.....
2. Size and clearance of cylinders.....
3. Area of heating surface.....
4. Area of grate surface.....
5. Diameter of exhaust nozzles.....

	Total Quantities.	Whole Run.
6.	Duration .....hrs.	.....
7.	Weight of dry coal burned, including .4 weight of wood.lbs.	.....
8.	Weight of water evaporated corrected for moisture in the steam .....lbs.	.....
9.	Weight of ashes and refuse from ash-pan.....lbs.	.....
10.	Weight of cinders from smoke-box.....lbs.	.....
11.	Percentage of ash as found by calorimeter test....per cent	.....
12.	Total heat of combustion per lb. coal as found by calorimeter test.....B. T. U.	.....
	Power Data.	
13.	Mean effective pressure, high-pressure cylinders.....lbs.	.....
14.	Mean effective pressure, low-pressure cylinders.....lbs.	.....
15.	Average revolutions per minute.....rev.	.....
16.	Indicated horse-power, high-pressure cylinders.....H. P.	.....
17.	Indicated horse-power, low-pressure cylinders.....H. P.	.....
18.	Indicated horse-power, total.....H. P.	.....
19.	Pull on drawbar .....lbs.	.....
20.	Dynamometer horse-power .....H. P.	.....
	Averages of Observations.	
21.	Average boiler pressure.....lbs.	.....
22.	Average steam-chest pressure.....lbs.	.....
23.	Average temperature of smoke-box.....°	.....
24.	Average draught suction....."	.....
25.	Average temperature of feed-water .....°	.....
26.	Average temperature of atmosphere.....°	.....
27.	Average percentage of moisture in the steam....per cent	.....
28.	Maximum percentage of moisture in the steam...per cent	.....

Hourly Quantities.

		Whole Run.
29.	Weight of dry coal burned per hour.....lbs.	.....
30.	Weight of dry coal burned per hour per square foot of grate surface.....lbs.	.....
31.	Weight of coal burned per hour per square foot of heating surface.....lbs.	.....
32.	Weight of water evaporated per hour.....lbs.	.....
33.	Equivalent weight of water evaporated per hour with feed-water at 100° and pressure at 70 lbs.....lbs.	.....
34.	Equivalent weight of water from 100° at 70 lbs. evaporated per square foot of heating surface.....lbs.	.....

Principal Results, Complete Engine and Boiler.

35.	Coal consumed per I. H. P. per hour.....lbs.	.....
36.	Coal consumed per dynamometer horse-power per hour .....lbs.	.....
37.	Weight of "standard coal" consumed per I. H. P. per hour .....lbs.	.....
38.	Weight of "standard coal" consumed for a dynamometer horse-power per hour.....lbs.	.....

Boiler Results.

39.	Water evaporated per pound of coal.....lbs.	.....
40.	Equivalent evaporation per pound of coal from and at 212°..... .....lbs.	.....
41.	Equivalent evaporation per pound of combustible from and at 212°.....lbs.	.....
42.	Heat imparted to each pound of steam used from average temperature of feed at average steam pressure in British thermal units.....	.....

Cylinder Data.

43.	Mean initial pressure above atmosphere.....lbs.	.....	
		H. P. Cyl.	L. P. Cyl.
44.	Cut-off pressure above zero.....lbs.	.....	.....
45.	Release pressure above zero.....lbs.	.....	.....
46.	Compression pressure above zero.....lbs.	.....	.....
47.	Lowest back pressure above or below atmosphere .....lbs.	.....	.....
48.	Proportion of forward stroke completed at cut-off	.....	.....
49.	Proportion of forward stroke completed at release	.....	.....
50.	Proportion of return stroke uncompleted at compression	.....	.....

Cylinder Results.

		H. P. Cyl.	L. P. Cyl.
51.	Total water consumed per indicated horse-power per hour corrected for moisture in steam.....lbs.		
52.	Water consumed per I. H. P. per hour by cylinders alone (from line 51 less all measured losses).....lbs.		
53.	Steam accounted for by indicators at cut-off.lbs.	.....	.....
54.	Steam accounted for by indicators at release.lbs.	.....	.....
55.	Proportion of feed-water used by cylinders (line 52) accounted for at cut-off.....lbs.	.....	.....
56.	Proportion of feed-water used by cylinders accounted for at release .....lbs.	.....	.....
57.	Total heat supplied by boiler to cylinders per hour in British thermal units.....	.....	.....
58.	Total heat supplied by boiler to cylinders per minute per indicated horse-power in British thermal units.....	.....	.....
59.	Total heat supplied by boiler to cylinders per minute per dynamometer horse-power in British thermal units.....	.....	.....

Reports should give a copy of a set of sample indicator diagrams, also combined diagram (in case of compound engines) and a chart showing graphically the principal data.

SUPPLEMENT.

Description of Norfolk & Western Indicator Rigging. Fig. 1, General Arrangement. Fig. 2, Details.

This form of indicator rigging involves the use of a lever (supported from the running-board by a suitable bracket), and connected at its lower end to the cross-head (by a link 12 in. long). The indicator drum cord takes its motion from a square bar working in suitable guides and connected by a short link to the main lever. In order to secure a perfectly parallel motion, the length of the cross-head link should bear the same ratio to the length of the indicator-bar link as the full length of the main lever bears to the distance from fulcrum of main lever to point of connection of the indicator-bar link. For an engine with 24-inch stroke this ratio should be 1 to 6, in order to produce an indicator card 4 inches long, and the long and short links should be 12 inches and 2 inches, respectively.

Description of Valve Motion Indicator. Fig. 3.

In this apparatus a string is wound around the groove on one end of drum, and passed over proper pulleys until it leads off in a line with the motion of the cross-head, and the other end is attached to the cross-head,

so that any motion of the piston is communicated by the cord to the drum, causing corresponding rotation.

A cord from the pen-bar is led over suitable pulleys and attached to valve rod in the same manner. The combination of the two motions, as will be seen, will give an elliptical diagram in which the abscissæ represent the position of the piston, and the ordinates the position of the valve.

Description of Boiler Lever Indicator. Fig. 4.

This apparatus consists of a spirit level mounted in a saddle which slides on an arc of a large circle. This arc is graduated, and should be sufficiently curved to operate on the heaviest grade upon which the engine will be tested.

By putting the engine on jacks or cranes, and giving different elevations to the boiler, the height of water may be measured by means of a meter to certain points on the gauge-glass, and a corresponding table made, which will denote the quantity of water in the boiler for each different angular position of the boiler. These figures can be used to make corrections on the meter readings, allowing for inclinations of the track on which the engine is standing by simply pushing the spirit lever to a horizontal position and noting the reading on the indicator.

SPECIFICATIONS AND TESTS FOR IRON LOCOMOTIVE BOILER TUBES, EXTRA QUALITY.

At the convention of 1895 the following Specifications and Tests for Iron Locomotive Boiler Tubes were adopted as standard (see page 127, report 1895); modified in 1896 (see pages 332, 333, report 1896). Revised, June, 1904.

SPECIFICATIONS FOR IRON LOCOMOTIVE BOILER TUBES.

1. Tubes are to be made of knobbled, hammered charcoal iron, lap-welded.

2. Tubes must be of uniform thickness throughout, except at weld, where an additional thickness of .015 will be allowed. They must be circular within .02 inch, and the mean diameter must be within .015 inch of the size ordered. They must be within .01 inch of the thickness specified and not less than the length ordered, but may exceed this by .125 inch.

3. The minimum weights for tubes of various diameters and thicknesses are given in the following table:

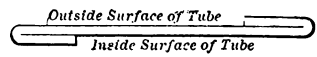
Outside Diameter.	Nominal B. W. G.	Thickness M. M. G.	Minimum weight per foot.
		Inches.	Lbs.
1¾ inch	No. 13	.095	1.65
	" 12	.110	1 89
	" 11	.125	2 07
	" 10	.135	2.29
2 inch	" 13	.095	1.91
	" 12	.110	2.17
	" 11	.125	2.38
	" 10	.135	2.64
2¼ inch	" 13	.095	2.16
	" 12	.110	2.46
	" 11	125	2.70
	" 10	.135	2.99
2½ inch	" 12	.110	2.73
	" 11	.125	3.02
	" 10	.135	3 37

SURFACE INSPECTION.

4. Tubes must have a smooth surface, free from all laminations, cracks, blisters, pits and imperfect welds. They must be free from bends, kinks and buckles, and from evidence of unequal contraction in cooling or injury in manipulation.

PHYSICAL TESTS.

5. Bending Tests.— Strips ½ inch in width by 6 inches in length, planed lengthwise from tubes, after having been heated to a cherry red and quenched in water at 80° F., shall bend in opposite directions at each end, as shown in sketch below, without cracks or flaws, and when nicked and broken by slight blows, these strips must show a fracture wholly fibrous.



6. Expanding Test.— Sections of tubes 12 inches long shall be heated a length of 5 inches to a bright cherry red in daylight and then placed in a vertical position and a smooth taper steel pin at blue heat will be driven into the end of the tube by light blows of a 10-pound hammer. Under this test the tube must stretch to 1⅛ times its original diameter without splitting or cracking. The pin used shall be of tool steel tapered 1½ inches to the foot. In making this test, care must be taken to see that the end of the tube is smoothly trimmed.

7. One tube is to be tested, as required in paragraphs 5 and 6, in each lot of 250 tubes or less.

8. CRUSHING TEST.— A section of tube 2½ inches long, when placed vertically on the anvil of a steam hammer and subjected to a series of light blows, must crush to a height of 1⅛ inches without splitting in either direction and without cracking or bending at weld.

9. HYDRAULIC TEST.— Before shipping, each tube must be tested by manufacturer to 500 pounds per square inch, and each tube must be plainly marked in the middle: "Knobbled charcoal, tested to 500 pounds pressure."

10. In addition to the above tests, tubes which, when inserted into boilers, split or break while being expanded or beaded, and also individual tubes which fail to pass surface inspection will be rejected and returned to the makers at their expense.

11. ETCHING TEST.— In case of doubt as to the quality of material, the following test shall be made to detect the presence of steel. A section of tube, turned or ground to a perfectly true surface on the end, will be polished free from dirt or cracks, and the end of the tube will be suspended in a bath of nine parts water, three parts sulphuric acid and one part hydrochloric acid. The bath will be prepared by placing water in a porcelain dish, adding the sulphuric and then the hydrochloric acid. The chemical action must be allowed to continue until the soft parts are sufficiently dissolved so that the iron tube will show a decided ridged surface, with the weld very distinct, while the steel tube will show a homogeneous surface.

SPECIFICATION FOR SEAMLESS, COLD DRAWN STEEL LOCOMOTIVE BOILER TUBES.

1. Tubes are to be cold drawn, seamless and made of open hearth steel. It is desired that the steel from which the tubes are manufactured should have the following chemical composition:

	Per cent.
Carbon	.15 to .20
Manganese	.45 to .55
Sulphur, below	.03
Phosphorus, below	.03

Tubes containing more than .03 phosphorus or sulphur will be rejected.

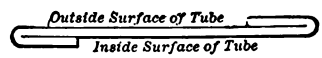
2. Tubes must be of uniform thickness throughout. They must be circular within .02 of an inch and the mean diameter must be within .015 inch of the size ordered. They must be within .01 inch of the thickness specified and not less than the length ordered, but may exceed this by .125 inch. They must be free from bends, kinks and buckles.

3. The minimum weights of the tubes of various diameters and thicknesses are given in the following table:

Outside Diameter.	Nominal B. W. G.	Thickness M. M. G.	Minimum weight per foot.
		Inches.	Lbs.
1¾ inch	No. 13	.095	1.69
	" 12	.110	1.92
	" 11	.125	2.15
	" 10	135	2.29
2 inch	" 13	.095	1.91
	" 12	.110	2.19
	" 11	.125	2.47
	" 10	.135	2.65
2¼ inch	" 13	.095	2.16
	" 12	.110	2.48
	" 11	.125	2.80
	" 10	.135	3.01
2½ inch	" 12	.110	2.73
	" 11	.125	3.04
	" 10	.135	3.41

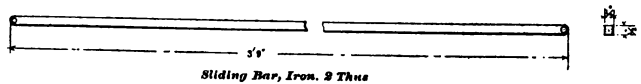
PHYSICAL TESTS.

4. Bending Test.— Strips ½ inch in width by 6 inches in length, planed lengthwise from tubes, after having been heated to a cherry red and quenched in water at 80 degrees F., shall bend in opposite directions at each end, as shown in sketch below without cracks or flaws.

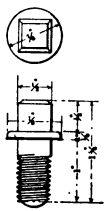


5. Expanding Test.— Sections of tubes 12 inches long shall be heated a length of five inches to a bright cherry red in daylight and then placed in a vertical position and a smooth taper steel pin at blue heat will be driven into the end of the tube by light blows of a 10-pound hammer. Under this test the tube must stretch to 1⅛ times its original diameter without splitting or cracking. The pin used shall be of tool steel tapered 1½ inches to the foot. In making this test care must be taken to see that the end of the tube is smoothly trimmed.

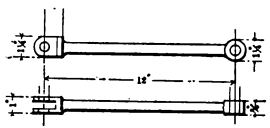
6. Crushing Test.— A section of tube 2½ inches long, when placed vertically on the anvil of a steam hammer and subjected to a series of light blows, must crush to a height of 1⅛ inches without splitting in either direction.



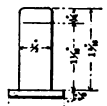
Sliding Bar, Iron. 2 Thus



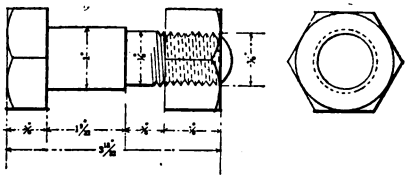
Clamp Screw, Iron. 2 Thus



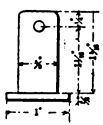
Connecting Rod, Iron. 2 Thus



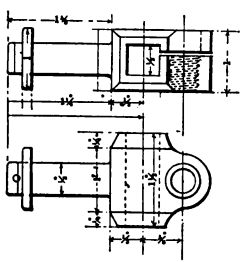
Link Pin, Iron. 2 Thus



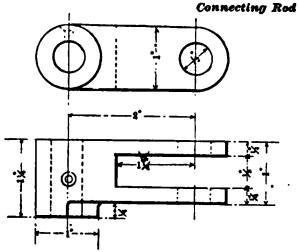
Indicator Lever Bolt, Iron. 2 Thus



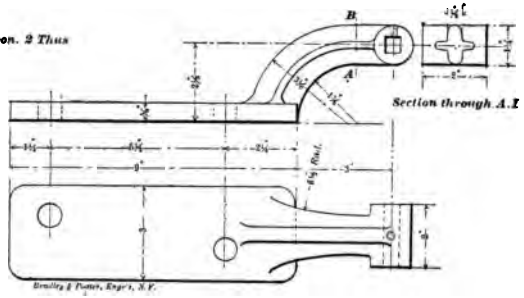
Connecting Rod Pin, Iron. 2 Thus



Sliding Bar Clamp, Brass. 2 Thus



Connecting Link, Brass. 2 Thus



Sliding Bar Guide, Cast Iron. 4 Thus

FIGURE 2.

7. FLATTENING TEST.—A test piece of tube 6 inches long, when flattened lengthwise cold until the sides are separated by a distance equal to the gauge of the tube, must not show any splits or cracks.

8. One tube is to be tested as required in paragraphs 4, 5, 6 and 7 in each lot of 250 tubes, or less.

9. Each tube must be subjected by the manufacturer to an internal pressure of 1,000 pounds to the square inch and must be plainly stenciled, "Seamless Steel Tubes, tested to 1,000 pounds."

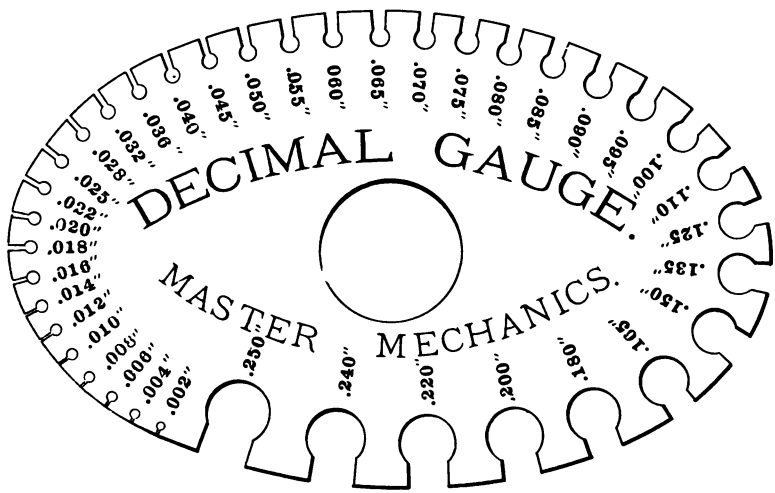
DECIMAL GAUGE.

At the convention of 1895 the following was adopted as a standard Decimal Gauge:

1st. The micrometer caliper should be used for laboratory and tool-room work, and in the shop when specially desired.

2d. The solid notch gauge should be used for general shop purposes.

3d. The form of this gauge shall be an ellipse whose major axis is 4 inches, the minor axis 2.5 inches, and the thickness .1 inch, with a central hole .75 inch in diameter.



4th. The notches in this gauge shall be as follows:

.002″	.022″	.060″	.110″
.004″	.025″	.065″	.125″
.006″	.028″	.070″	.135″
.008″	.032″	.075″	.150″
.010″	.036″	.080″	.165″
.012″	.040″	.085″	.180″
.014″	.045″	.090″	.200″
.016″	.050″	.095″	.220″
.018″	.055″	.100″	.240″
.020″	.....	.....	.250″

5th. All notches to be marked as in the above list.

6th. The gauge must be plainly stamped with the words "Decimal Gauge" in capital letters .2 inch high, and below this the words "Master Mechanics."

7th. In ordering material, the term gauge shall *not* be used, but the thickness ordered by writing the decimal as in above list. For sizes over ¼ inch, the ordinary common fractions may be used.

BRIGGS STANDARD WROUGHT-IRON PIPE THREADS.

At the convention of 1899, what is known as the Briggs Standard, as determined by the Pratt & Whitney gauges, of threads for wrought-iron pipe and couplings, was adopted as a standard of the Association.

The gauges used by the Pratt & Whitney Company were made by them from an autograph copy of a table made by Mr. Robert Briggs personally, who originally established and published these standard threads. A copy of it is as follows:

STANDARD DIMENSIONS OF WROUGHT-IRON WELDED TUBES. BRIGGS STANDARD.

Diameter of Tube.			Thickness of metal.	Screwed Ends.	
Nominal inside.	Actual inside.	Actual outside.		Number of threads per inch.	Length of perfect screw.
Inches.	Inches.	Inches.	Inch.	No.	Inch.
⅛	0.270	0.405	0.068	27	0.19
¼	0.364	0.540	0.088	18	0.29
⅜	0.494	0.675	0.091	18	0.30
½	0.623	0.840	0.109	14	0.39
¾	0.824	1.050	0.113	14	0.40
1	1.048	1.315	0.134	11½	0.51
1¼	1.380	1.660	0.140	11½	0 54
1½	1.610	1.900	0.145	11½	0.55
2	2.067	2.375	0.154	11½	0.58
2½	2.468	2.875	0.204	8	0.89
3	3.067	3.500	0.217	8	0.95
3½	3.548	4.000	0.226	8	1.00
4	4.026	4.500	0.237	8	1.05
4½	4.508	5.000	0.246	8	1.10
5	5.045	5.563	0.259	8	1.16
6	6.065	6.625	0.280	8	1.26
7	7.023	7.625	0 301	8	1.36
8	7 982	8.625	0.322	8	1.46
9	9 000	9.688	0.344	8	1.57
10	10.019	10.750	0.366	8	1.68

Tapers of conical tube ends, 1 in 32 to axis of tube. (¾-inch per foot.)

By the late action of the Manufacturers of Wrought-Iron Pipe, 9-inch outside diameter has been excepted from the original list, as above noted, the diameter now adopted being 9.625 instead of 9.688 inches given in the Briggs table.

⅛-inch	
¼ "	
⅜ "	
½ "	
¾ "	
1 "	
1¼ "	
1½ "	
2 "	
2½ "	
3 "	
3½ "	
4 "	

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PHYSICAL REQUIREMENTS.

3. Tensile strength — not less than 80,000 lbs. per square inch.
Elongation in two inches — not less than 20 per cent.
Reduction in area — not less than 25 per cent.

TESTS.

4. One test per melt will be required, the test specimen to be taken from either end of any axle with a hollow drill, half-way between the center and the outside, the hole made by the drill to be not more than 2 inches in diameter nor more than 4½ inches deep. The standard turned test specimen, ½ inch in diameter and 2 inches gauge length, shall be used to determine the physical properties. (See Fig. 1.)

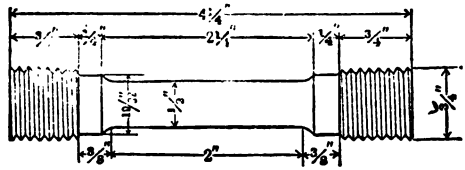

FIG. 1.

Drillings or turnings from the tensile specimen shall be used to determine the chemical properties.

STAMPING AND MARKING.

5. Each axle must have heat number and manufacturer's name plainly stamped on one end, with stamps not less than ⅜ inch high, and have order number plainly marked with white lead.

INSPECTION.

6. All axles must be free from seams, pipes and other defects, and must conform to drawings accompanying these specifications.

7. Axles must be rough-turned all over, with a flat-nosed tool, cut to exact length, have ends smoothly finished and centered with sixty-degree centers.

8. Axles failing to meet any of the above requirements, or which prove defective on machining, will be rejected.

SPECIFICATIONS FOR LOCOMOTIVE FORGINGS.

MATERIAL.

1. Open-hearth steel.

CHEMICAL REQUIREMENTS.

2. Phosphorus, not to exceed..... .05 per cent.
Sulphur, not to exceed..... .05 per cent.
Manganese, not to exceed..... .60 per cent.

PHYSICAL REQUIREMENTS.

3. Tensile strength — not less than 80,000 lbs. per square inch.
Elongation — not less than 20 per cent in two inches.
Reduction in area — not less than 25 per cent.

TESTS.

4. One test per melt will be required, the test specimen to be cut cold from the forging, or full-sized prolongation of same, paralliel to the axis of the forging and half-way between the center and the outside.

5. The standard turned specimen, ½ inch in diameter and 2 inches gauge length, shall be used to determine the physical properties. (See Fig. 1.) Drillings or turnings from the tensile specimen shall be used to determine the chemical properties.

STAMPING AND MARKING.

6. Each forging must have heat number and name of manufacturer plainly stamped on one end with figures not less than ⅜ inch high, and have order number plainly marked with white lead.

INSPECTION.

7. All forgings must conform to drawings which accompany these specifications, and be free from seams, pipes and other defects.

8. Any forgings failing to meet any of the above requirements, or which prove defective on machining, will be rejected.

SPECIFICATIONS FOR STEEL BLOOMS AND BILLETS FOR LOCOMOTIVE FORGINGS.

MATERIAL.

1. Open-hearth steel.

PHYSICAL REQUIREMENTS.

2. Grade "A":
Tensile strength, 70,000 lbs. per square inch.
Elongation in two inches, 20 per cent.

3. Grade "B":
Tensile strength, 80,000 lbs. per square inch.
Elongation in two inches, 17 per cent.

CHEMICAL ANALYSIS.

4. Grade "A":

Carbon	.25 to .40 per cent.
Phosphorus, not to exceed	.06 per cent.
Sulphur, not to exceed	.06 per cent.
Manganese, not to exceed	.60 per cent.

5. Grade "B":

Carbon	.35 to .50 per cent.
Phosphorus, not to exceed	.05 per cent.
Sulphur, not to exceed	.05 per cent.
Manganese, not to exceed	.60 per cent.

TESTS.

6. One test per melt will be required, the test specimen to be cut cold from the bloom, parallel to its axis and half-way between the center and the outside. The standard turned test specimen, ½ inch in diameter and 2 inches gauge length, shall be used to determine the physical properties. (See Fig. 1.) Drillings or turnings from the tensile specimen shall be used to determine the chemical properties.

STAMPING AND MARKING.

7. Each bloom or billet must have heat number and manufacturer's name plainly stamped on one end, with stamps not less than ⅜ inch, and have order number plainly marked with white lead.

INSPECTION.

8. Blooms and billets must be free from checks, pipes and surface defects. Any blooms or billets chipped to a depth greater than ½ inch will be rejected.

9. Any billet or bloom failing to meet the above requirements will be rejected and held subject to disposal by manufacturers.

10. Inspector to have the privilege of taking drillings from the center of the top bloom or billet of the ingot in order to determine the amount of segregation.

Grade "A" is intended for rod straps and miscellaneous forgings.

Grade "B" is intended for driving and truck axles, connecting rods, crank pins and guides.

FITTINGS FOR LUBRICATORS.

At the convention of 1906 the Committee on Locomotive Lubrication proposed a standard location of holding arm shoulder and oil and steam connection joint faces; also a system of fittings and joints for all connections. Fig. 1 shows the location for connection of joints and holding arm. Figs. 2, 3, 4 and 5 show pipe joints and fittings, and Fig. 6 illustrates the holding arm proposed.

On reference to letter ballot they were adopted as standard. They are as shown herewith.

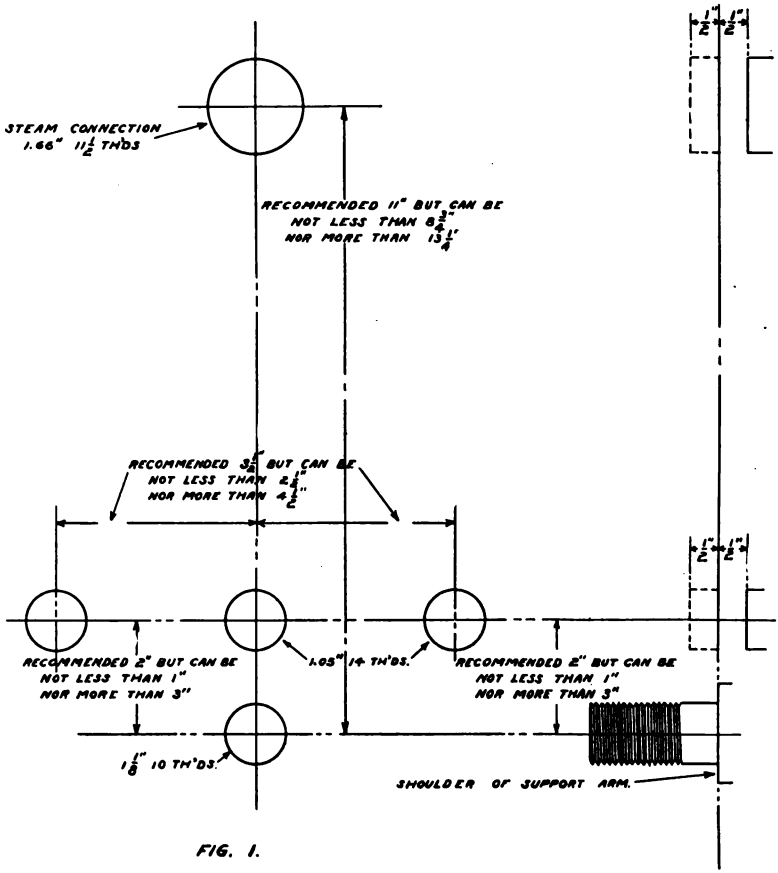
STEAM CONNECTION
1.66" 11½ TH'DS
RECOMMENDED 11" BUT CAN BE
NOT LESS THAN 8¾"
NOR MORE THAN 13¼"
RECOMMENDED 3½" BUT CAN BE
NOT LESS THAN 2½"
NOR MORE THAN 4½"
RECOMMENDED 2" BUT CAN BE
NOT LESS THAN 1"
NOR MORE THAN 3"
1.05" 14 TH'DS.
RECOMMENDED 2" BUT CAN BE
NOT LESS THAN 1"
NOR MORE THAN 3"
1⅛" 10 TH'DS.
SHOULDER OF SUPPORT ARM.
½"
½"

FIG. 1.

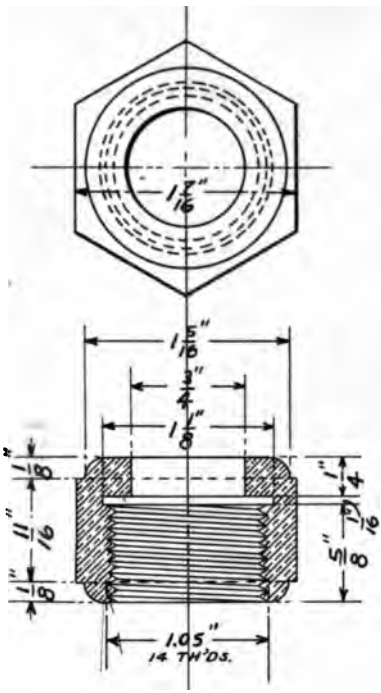

FIG. 2.

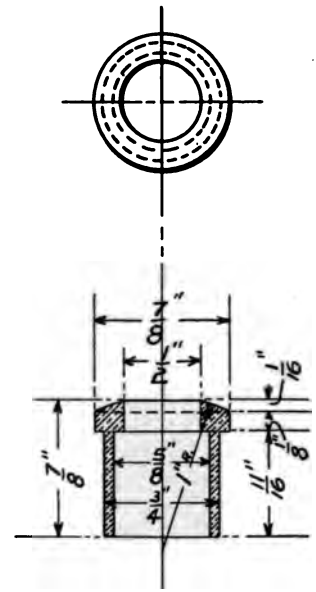

FIG. 3.

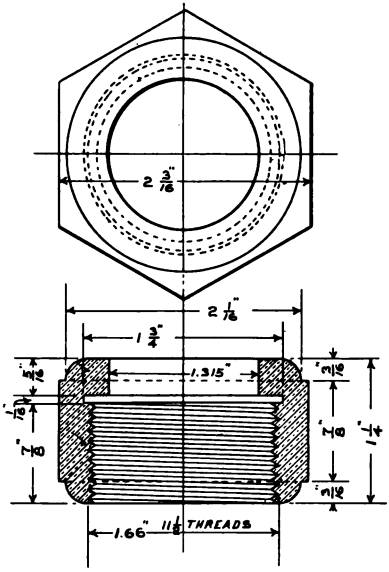

FIG. 4

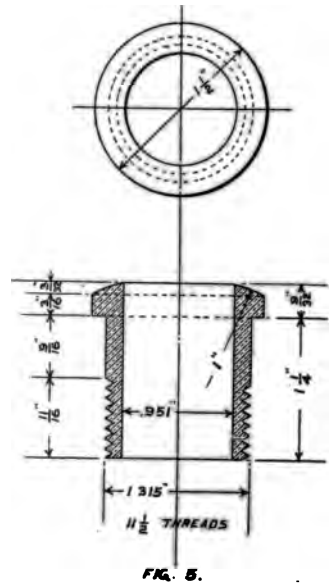

FIG. 5.

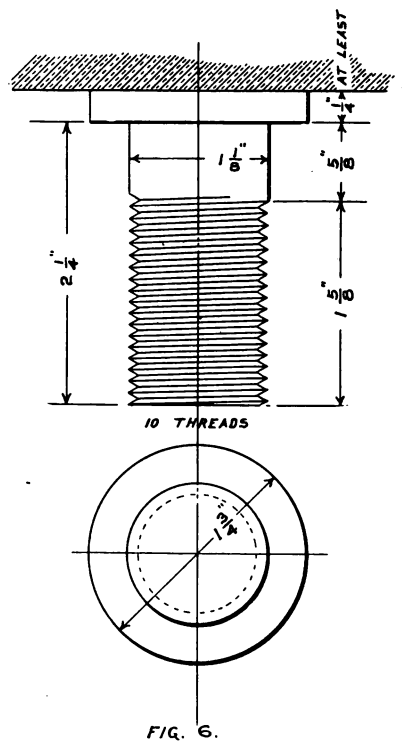

FIG. 6.

SPECIFICATIONS FOR FOUNDRY PIG IRON.

At the convention of 1906 specifications for foundry pig iron were proposed, and on reference to letter ballot were adopted as standard. They are as follows:

The material desired under this specification is an open-grain foundry pig conforming to and graded by the following detail specifications:

Combined carbon	.40 to .70 per cent.
Manganese	.40 to .80 per cent.
Phosphorus	.40 to .80 per cent.
Sulphur, not over	.06 per cent.

The grades are determined by the amount of silicon, in accordance with the attached schedule:

Grade No. 1, silicon	3.00 to 2.50 per cent.
Grade No. 2, silicon	2.50 to 2.00 per cent.
Grade No. 3, silicon	2.00 to 1.50 per cent.
Grade No. 4, silicon	1.50 to 1.00 per cent.

Each carload, or its equivalent, shall be considered as a unit. At least one pig shall be selected at random for each four tons of every carload and so as to fairly represent it.

Drillings shall be taken so as to fairly represent the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis.

In case of disagreement between buyer and seller, an independent analyst, to be mutually agreed upon, shall be engaged to sample and analyze the iron. In this event one pig shall be taken to represent every two tons.

The cost of this sampling and analysis shall be borne by the buyer if the shipment is proved up to specifications, and by the seller if otherwise.

SPECIFICATIONS FOR LOCOMOTIVE CYLINDER CASTINGS, CYLINDER BUSHINGS, CYLINDER HEADS, STEAM CHESTS, VALVE BUSHINGS AND PACKING RINGS.

At the convention of 1906 the following specifications were proposed, and on reference to letter ballot were adopted as standard:

The material used in such castings must conform to the following specifications:

Silicon	1.25 to 1.60 per cent.
Phosphorus	.50 to .80 per cent.
Sulphur	.06 to .10 per cent.
Manganese	.30 to .60 per cent.
Combined carbon	.50 to .70 per cent.
Graphite carbon	2.75 to 3.25 per cent.

Tensile strength, 25,000 lbs. per sq. inch minimum.

Transverse strength, 3,000 lbs. minimum on 1¼-inch round bar, 12 inches between supports.

Deflection, .10 inch minimum on transverse test.

Shrinkage, ⅛ inch in 1 foot as a maximum.

The quality of the iron going into castings under specification shall be determined by means of the "arbitration bar." This is a bar 1¼ inches in diameter and 15 inches long. It shall be prepared as stated further on and tested transversely. The tensile test is not recommended, but in case it is called for it may be made from any of the broken pieces of the transverse test. The expense of the tensile test shall fall on the purchaser.

The tensile test piece should be prepared with threaded ends, 1¼ inches in diameter, and with a central neck of 0.8 inch diameter, 1 inch between shoulders, with a 7-32-inch radius at the shoulders, the shoulders being 1 inch in diameter and ¼ inch in length to the thread, the total length of piece being about 3½ inches.

Two sets of two bars shall be cast from each heat, one set from the first and the other set from the last iron going into the castings. Where the heat exceeds 20 tons an additional set of two bars shall be cast for each 20 tons or fraction thereof above this amount. In case of a change of mixture during the heat one set of two bars shall also be cast for every mixture other than the regular one. Each set of bars is to go in a single mold. The bars shall not be rumbled or otherwise treated, being simply brushed off before testing.

The transverse test shall be made on all the bars cast with supports 12 inches apart, load applied at the middle, and deflection at rupture noted. One bar of every two of each set made must fulfil the requirements to permit acceptance of the castings represented.

The bars shall be molded two in a flask and cast on end; the bottom of the bar being 1-16 inch smaller in diameter than the top, to allow for draft. Pattern shall not be rapped before withdrawing. The flask is to be rammed up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled.

The rate of application of the load shall be from 20 to 40 seconds for a deflection of 0.10 inch.

Borings from the broken pieces of the arbitration bar shall be used for the chemical determinations. One determination for each mold shall be required.

For cylinder heads, steam chests and packing rings the silicon must run between 1.60 and 1.80 per cent, the other elements remaining as above. If cylinder castings are to be bushed from the start and also have valve bushings or false valve seats, they should be made of this latter grade of iron.

RECOMMENDATIONS.

At the convention in 1872 the following recommendations were adopted:

"In the matter of cost of keeping up the repairs of engines engaged in switching service exclusively, that an allowance of six miles per hour for the time that such engines are in actual use be allowed:

"That for engines running local freight trains an allowance of six per cent to the train mileage be added for switching:

"That where engines run empty to exceed one-half mile between where the trains are taken or left and the roundhouse, such mileage should be computed, and that for engines running through freight or passenger trains no computation should be made for switching:

SPECIFICATIONS AND TESTS FOR CAST-IRON WHEELS.

At the convention of 1888 the following Specifications and Tests for Cast-iron Wheels were adopted as standard. (See pages 151-154, report 1888.) In 1891 these were changed to Recommendations. (See pages 160, 161, report 1891.)

The specifications and tests are as follows:

Specifications for Cast-iron Wheels.

1. The chills in which the wheels of any one wheelmaker are cast shall be of equal diameters, and the same chill must not vary at different points more than one-sixteenth of an inch in diameter.

2. There shall not be a variation of more than one-half inch in the circumference of any given number of wheels of the same nominal diameter, furnished by any one maker, and the same wheel must not vary more than one-sixteenth of an inch in diameter. The body of the wheel must be smooth and free from slag or blow holes. The tread must be free from deep and irregular wrinkles, slag, chill cracks and sweat or beads in the throat which are one-eighth of an inch or over in diameter, or which occur in clusters of more than six inches in length.

3. The wheels broken must show clean, gray iron in the plates; the depth of pure white iron must not exceed seven-eighths of an inch or be less than three-eighths of an inch in middle of the tread, and shall not be less than three-sixteenths of an inch in the throat. The depth of the white iron shall not vary more than one-fourth of an inch around the tread on the rail line in the same wheel.

4. Wheels shall not vary from the specified weight more than two per cent.

5. The flange shall not vary in the same wheel more than three thirty-seconds of an inch from its mean thickness.

6. The single plate part of a 33-inch wheel, known as the Washburn pattern, shall not be less than five-eighths of an inch in thickness in a

wheel weighing from 550 to 575 pounds, and not less than three-fourths of an inch in thickness in a wheel weighing from 575 to 600 pounds.

Tests for Cast-iron Wheels.

1. For each hundred wheels which pass inspection and are ready for shipment, one representative wheel shall be taken at random and subjected to the following test:

The wheel shall be placed flange downward on an anvil block weighing seventeen hundred (1,700) pounds, set on rubble masonry at least two feet deep, and having three supports not more than five inches wide for the wheel to rest upon. It shall be struck centrally on the hub by a weight of one hundred and forty (140) pounds, falling from a height of twelve (12) feet. Should this wheel stand five (5) blows without breaking into two or more pieces, the hundred wheels shall be accepted. Or, wheels must be of such strength that 550 to 575 pound wheels shall require twenty (20) blows, and 575 to 600 pound wheels shall require thirty (30) blows of a hundred (100) pound drop falling seven (7) feet on the plate close to the rim to break a piece out — the wheel resting upon a cast-iron plate weighing not less than one thousand (1,000) pounds.

2. Should in either case the test wheel break into two or more pieces with less than the required number of blows, then a second wheel shall be taken from the same lot and similarly tested. If the second wheel stands the test, it shall be optional with the inspector whether he shall test a third wheel or not. If he does not so elect, or if he does and the third wheel stands the test, the hundred wheels shall be accepted.

3. The above tests shall apply to standard weight wheels from 26 inches to 42 inches diameter, used on standard gauge roads.

Form of Contract.

THIS INDENTURE, made this.....day of.....18.., between..... party of the first part, and.....party of the second part, WITNESSETH:

1. The party of the first part hereby agrees to furnish to the party of the second part, free on board cars at.....chilled cast-iron wheels, ... inches in diameter under the following conditions:

2. The party of the second part hereby agrees to pay to the party of the first part.....dollars for each wheel furnished, and to keep an accurate record of the mileage made by the wheels placed in service under cars in passenger equipment and under locomotives and tenders, and an accurate record of the number of months of service of the wheels placed under cars in freight equipment.

3. The party of the second part hereby agrees when any wheel furnished under this contract is scrapped, to furnish to the party of the first part a statement which will show

1.—The wheel number.

2.—The service in which the wheel ran.

3.—The amount of service in months or miles.

4.—The cause of failure.

5.—A charge against the party of the first part of fifty-five per cent (55 per cent) of the price of the wheel mentioned above.

6.—A credit to the party of the first part of

....cents per 1,000 miles for 36 in. passenger equipment
.... " " " 33 " " "
.... " " " 30 " " "
.... " " " 36 in. locomotives and tenders
.... " " " 33 " " "
.... " " " 30 " " "
.... " " " 28 " " "
.... " " " 26 " " "
.... " per month for 36 in. freight equipment
.... " " " 33 " " "
.... " " " 30 " " "

except in the case of wheels made flat by sliding, or removal for sharp flanges or other unfair treatment, which have not made sufficient service to balance the charge against the party of the first part as above; in such case a service credit shall be made which shall balance the charge.

4. The party of the first part hereby agrees that on presentation of the statement to pay to the party of the second part any balance due from lack of sufficient service on the part of the wheels (with above exceptions) to balance the charge; and the party of the second part hereby agrees to pay to the party of the first part any balance due as shown by the aforesaid statement — settlements to be made quarterly. It is, however, understood and agreed that no credit shall be allowed for excessive mileage for time service on freight wheels beyond the time guaranteed.

5. The party of the second part hereby agrees to hold, subject to the inspection of the party of the first part, for a period of thirty days after the said statement has been rendered, any wheels (with above exceptions) which have not earned for themselves a credit equal to the amount charged against them.

Service Guarantee.

36 inch passenger wheels.....	70,000 miles
33 " " "	60,000 "
36 inch engine and tender wheels	60,000 "
33 " " "	50,000 "
30 " " "	45,000 "
26 and 28 inch engine and tender wheels.....	40,000 "
Refrigerator, through line and cattle cars...	24 months
All other freight cars.....	48 "

Settlements of claims for non-performance of guaranteed service shall be made upon the basis of mileage and time guarantee as above.

AIR BRAKE AND SIGNAL INSTRUCTIONS.

At the convention of 1892 a code of Air Brake and Signal Instructions was adopted as Recommendation of the Association. Some modifications were made in 1898, and the modified rules are shown on pages 205-228, report 1898. Revised, June, 1904, as follows :

The title of the revised instructions should be,

"AIR BRAKE AND TRAIN AIR SIGNAL INSTRUCTIONS."

A.—GENERAL INSTRUCTIONS.

1. The following rules and instructions are issued for the government of all employes of this railroad whose duties bring them in contact with the maintenance or operation of the air brake and train air signal. They must be obeyed in all respects, as employes will be held responsible for the observance of same as strictly as for the performance of any other duty.

Every employe whose duties are connected in any way with the operation of the air brake will be examined from time to time as to his qualifications for such duties by the Inspector of Air Brakes or other person appointed by the proper authority, and a record will be kept of such examination.

A book of information will be issued, in convenient form, giving a complete explanation of such parts of the air brake and train air signal equipment as is deemed necessary for the care and operation of same. Any employe of this railroad whose duties require a knowledge of the operation and maintenance of the air brake and air signal will be furnished with a copy of same upon application at place designated by special notice, and every employe will be held responsible for a full knowledge of his duties in the operation or maintenance of the air brake or signal equipment.

B.—INSTRUCTIONS TO ENGINEMEN.

Enginemen when taking charge of locomotives must see that the air brake apparatus on engine and tender is in good working order, and that the air pump and lubricator work properly; that the devices used for regulating main reservoir and train pipe pressures are adjusted at the authorized amount; that brake valve works properly in all its positions; and that, when brakes are fully applied, with cam type of driver brake the pistons do not travel less than 2 inches nor more than 3½ inches, and with other forms from 4 inches to 6 inches, and that the tender brake piston does not travel less than 6 inches nor more than 9 inches. They must know that the air signal responds by opening hose cock on its train pipe.

Enginemen must report to roundhouse foremen, in writing, at the end of the run, any defects in the air brake or train air signal apparatus.

MAKING UP TRAINS, TESTING BRAKES AT TERMINAL POINTS AND BEFORE STARTING DOWN SUCH GRADES AS MAY BE DESIGNATED BY SPECIAL INSTRUCTIONS.— The train pipe under the tender must always be blown out and maximum pressure obtained in main reservoir before coupling engine to train.

After the train has been charged with air pressure, the engineman shall, at the request of the inspector or trainmen, apply the brakes with full service application and leave them so applied until all brakes operated from the engine have been inspected and the signal given to release. The engineman must then release the brakes and must not leave the station until it has been ascertained that all brakes are released and he has been informed by the inspector, or trainmen, of the number of brakes in service and their condition. In testing passenger brakes, the American Railway Association code of train air signals for applying or releasing must be used, one of which signals must be given from the discharge valve on rear car.

Following the separation of couplings for local switching, or when engine or train has been parted for any purpose, the above test need not be complied with further than to ascertain, by test, that the rear brakes are responsive to brake valve on engine and that all brakes have properly released. However, when cars are added to train, the brakes on such cars must be inspected as in terminal test. When a passenger train back-up hose is to be used to control the train, the brakes must be applied for test with the back-up hose, and released from the brake valve on the locomotive.

4. SERVICE APPLICATION.— In applying the brakes to steady the train on descending grades, or for reducing speed for any purpose, an initial train pipe reduction of not less than five pounds must be made. Releasing brakes at low speeds must be performed with great care, dependent upon local conditions.

With freight trains, first allow the slack to run up against the locomotive. Great care must then be taken to apply the brakes with five to nine pounds reduction, according to length of train pipe, and not make a second reduction until the effect of the first reduction is felt on entire train, in order to prevent shocks which otherwise might be serious. When a freight train must be brought to a full stop, the train brakes must be held applied until stop is made.

In making a service stop with a passenger train, ALWAYS RELEASE THE BRAKES A SHORT DISTANCE BEFORE COMING TO A DEAD STOP, except on heavy grades, to prevent shocks at the instant of stopping. Even on moderate grades it is best to do this, and then, after release, to apply the brakes lightly, to prevent the train starting, so that when ready to start the release will take place quickly.

5. EMERGENCY APPLICATIONS.— The emergency application of the brakes must not be used, except in actual emergencies. Under such conditions the brake valve must be left in emergency position until train has come to a full stop.

ENGINEMAN'S STRAIGHT AIR BRAKE VALVE ON LOCOMOTIVES.

a — Always keep both brakes cut in and ready for operation, unless failure of some part requires cutting out.

b — Always carry an excess pressure of ten pounds, or more, in the main reservoir, as this is necessary to insure a uniformly satisfactory operation.

c — When using the automatic brake, keep the straight air brake valve in release position; and when using straight air, keep the automatic brake valve in running position; this to avoid driver and tender brakes sticking.

d — The straight air reducing valve should be kept adjusted at forty-five pounds, and the driver and tender brake safety valves at fifty-three pounds.

When a full application of straight air causes either or both safety valves to operate, it indicates that same are out of order, or too high adjustment of the reducing valve or too low adjustment of the safety valve, or leakage of same. Have them tested and adjusted.

6. BRAKES APPLIED FROM AN UNKNOWN CAUSE.— If it is found that the train is dragging as though the brakes were applied, without rapid falling of the train line pointer, the engineman must make an effort to release the brakes, which may be done as follows: First, if train pipe pressure is less than the authorized amount and the required excess pressure is carried in the main reservoir, move the handle of the brake valve to the full release position for a few seconds and then return it to the running position; secondly, should the train pipe be fully charged with pressure, apply the brakes with a five or ten pounds reduction, according to the length of the train pipe, and release the brakes in the usual manner. In case the brakes can not be released, the train must be stopped and the trainmen notified to examine the brakes.

If, however, the brakes go on suddenly with a fall of the train line pointer, it is evidence that (a) a conductor's valve has been opened, (b) a hose has burst or other serious leak has occurred, or (c) the train has parted. In such an event, the locomotive throttle should be closed and the brake valve handle immediately placed on lap or emergency position, to prevent the escape of air from the main reservoir, and left there until the train has stopped and the brake apparatus has been examined and the signal to release given.

7. BRAKING BY HAND.— NEVER USE THE AIR BRAKE when it is known that the trainmen are operating the brakes of the air brake cars by hand,

except in cases of emergency, as there is danger of injury to the trainmen by so doing.

8. CUTTING OUT BRAKES.— THE DRIVER AND TENDER BRAKES MUST ALWAYS BE USED AUTOMATICALLY AT EVERY APPLICATION OF THE TRAIN BRAKE, unless defective, except upon such grades as shall be designated by special instructions.

When necessary to cut out either driver or tender brake, on account of defects, it shall be done by turning the handle of the four-way cock in the triple valve down to a position midway between a horizontal and a vertical position, first releasing the brake and leaving the bleed cock open. With the special types of triple valve, close the cut-out cock in the branch pipe.

9. DOUBLE HEADERS.— When two or more locomotives are coupled in the same train, the brakes must be connected through to and operated from the head engine. For this purpose a cock is placed in the train pipe, just below the brake valve. Engineman of each locomotive except the head one must close this cock and carry the handle of brake valve in running position. He will start his air pump and let it run, as though he were going to use the brake, for the purpose of maintaining air pressure on his locomotive and enabling him to assume charge of the train brakes should occasion require it.

10. AN EXTRA AIR-BRAKE HOSE, COMPLETE, must always be carried on the locomotive, for repairs in case of burst hose. Upon locomotives having the air signal, a signal hose, complete, must also be carried for the same purpose.

C.— INSTRUCTIONS TO TRAINMEN.

11. MAKING UP TRAINS AND TESTING AIR BRAKES.— When the locomotive has been coupled to the train, or when two sections have been coupled together, the brake and signal couplings must be united, the cocks in the train pipes — both brake and signal — must all be open, except those at the rear end of the last car, which must be closed, and the hose hung up properly in the dummy coupling, when cars are so equipped.

After the train has been charged with air, the engineman must then be requested to apply the brakes. When he has done so, the brakes of each car must be examined to see if they are properly applied. When it is ascertained that each brake is applied, the engineman must be signaled to release the brakes. (In testing passenger brakes the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.) The brakes of each car must then be examined to see that each is released, and the engineman informed as to the number of brakes in service and their condition.

If any defect is discovered it must be remedied and the brakes tested again — the operation being repeated until it is ascertained that every-

thing is right. The conductor and engineman must then be notified that the brakes are all right. Following the separation of couplings for local switching, or when engine or train has been parted for any purpose, the above test need not be complied with other than to ascertain, by test, that the rear brakes are responsive to brake valve on engine and that all brakes have properly released. At points where there are no inspectors, trainmen must carry out these instructions. No passenger train must be started out from an inspection point with the brakes upon any car cut out or in a defective condition, without special orders from the proper officers. The air brakes must not be alone relied upon to control any freight train with a smaller proportion of cars with the air brake in service than provided for by special instructions. When hand brakes are also used they must be applied upon those cars next behind the air-braked cars, except in cases of emergency.

12. Detaching Locomotive or Cars.— First close the cocks in the train pipes at the point of separation, and then part the couplings, invariably by hand.

13. Couplings Frozen.— If the couplings are found to be frozen together or covered with an accumulation of ice, the ice must first be removed and then the couplings thawed out by a torch to prevent injury to the gaskets.

14. Brakes Sticking.— If brakes are found sticking, the signal "brakes sticking" must be given as hereafter prescribed by the American Railway Association, or by special rules, in which case, if the brakes can not be released from the locomotive, or if the brakes are applied to detached cars, the release may be effected by opening the bleed cock in the auxiliary reservoir until the air begins to release through the triple valve, when the reservoir cock must immediately be closed.

15. Train Breaking Into Two or More Parts.— First close the cock in the train pipe at the rear of the first section and signal the engineman to release the brakes. Having coupled to the second section, observe the rule for making up trains — first being sure that the cock in the train pipe at the rear of second section has been closed, if the train has broken into more than two sections. When the engineman has released the brakes on the second section, the same method must be employed with refence to the third section, and so on. When the train has been once more entirely united, the brakes must be inspected on each car to see that all are released before proceeding.

16. Cutting Out the Brake on a Car.— If, through any defect of the brake apparatus, it becomes necessary to cut out the brake upon any car, it may be done by closing the cock in the cross-over pipe near the center of the car where the quick-action brake is used, or by turning the handle of the cock in the triple valve to a position midway between a horizontal and a vertical, where the plain automatic brake is used, first releasing the brake. With the special types of triple valves, close the cut-

out cock in the branch pipe. When the brake has been thus cut out, the cock in the auxiliary reservoir must be opened and left open upon passenger cars, or held open until all the air has escaped from the reservoir upon freight cars. THE BRAKE MUST NEVER BE CUT OUT UPON ANY CAR UNLESS THE APPARATUS IS DEFECTIVE, and when it is necessary to cut out a brake the conductor must notify the engineman and also send in a report stating the reason for so doing.

17. CONDUCTOR'S VALVE.— Should it become necessary to apply the brakes from the train, it may be done by opening the conductor's valve placed in each car so equipped. THE VALVE MUST BE HELD OPEN UNTIL THE TRAIN COMES TO A FULL STOP, AND THEN MUST BE CLOSED AGAIN.

This method of stopping the train must not be used except in case of emergency.

18. BURST HOSE.— In the event of the bursting of a brake hose, it must be replaced and the brakes tested before proceeding, provided the train be in a safe place. If it is not, the train pipe cock immediately in front of the burst hose must be closed, and the engineman signaled to release. All the brakes to the rear of the burst hose must then be released by hand, and the train must then proceed to a safe place where the burst hose must be replaced and the brakes again connected and tested, so as to ascertain that the rear brakes are responsive, by test, to the brake valve on engine. One extra air brake hose complete should be carried by all crews and one extra signal hose complete carried by passenger crews for repairs.

19. BRAKES NOT IN USE.— When the air brakes are not in use, either upon the road or in switching, the hose must be kept coupled between the cars or hung up properly to the dummy couplings, when cars are so equipped.

20. PRESSURE-RETAINING VALVE.— When this valve is to be used, the trainmen must, at the top of the grade, test the brakes upon the whole train, and must then pass over the train and turn the handles of the pressure-retaining valves horizontally upon all or a part of the cars, as may be directed. At the foot of the grade, the handles must all be turned downward again. Special instructions will be issued as to the grades upon which these valves are to be used.

21. TRAIN AIR SIGNAL.— In making up trains, all couplings and car discharge valves on the cars must be examined to see if they are tight. Should the car discharge valve upon any car be found to be defective, it may be cut out of use upon that car by closing the cock in the branch pipe leading to the valve. The conductor must always be immediately notified when the signal has been cut out upon any car, and he must report the same for repairs.

In using the signal, pull directly down upon the cord during one full second for each intended blast of the signal whistle, and allow three seconds to elapse between the pulls.

22. REPORTING DEFECTS TO INSPECTORS.— Any defect in either the air brake or air signal apparatus discovered must be reported to the inspector at the end of the run; or, if the defect be a serious one in passenger service, it must be reported to the nearest inspector, and it must be remedied before the car is again placed in service.

D.— INSTRUCTIONS TO ENGINE-HOUSE FOREMEN.

23. GENERAL.— It is the duty of the engine-house foremen to see that the air brake and signal equipment is properly inspected upon each locomotive after each run. It must be ascertained that all pipe joints, connections and all other parts of the apparatus are air tight, duplex gauges tested every thirty days, and that the apparatus is in good working order.

24. AIR PUMP.— The air pump must be tested under pressure, and if found to be working imperfectly in any respect, it must be put into thoroughly serviceable condition.

25. PUMP GOVERNOR.— The pump governor should cut off the steam supply to the pump when authorized pressure has been obtained.

26. BRAKE VALVE.— This valve must be kept clean and known to be in working order in all its positions, before the locomotive leaves the engine-house.

27. ADJUSTMENT OF BRAKES.— The driver brakes must be so adjusted that the piston travel on the cam type will be not less than 2 inches nor more than 3½ inches, and in other forms not less than 4 inches nor more than 6 inches. When the cam brake is used care must be taken to adjust both cams alike, so that the point of contact of the cams shall be in line with the piston rod. The tender brake must be adjusted by means of the dead truck levers, so that the piston travels not less than six inches when the air brake is applied and the hand brake is released. This adjustment must be made whenever the piston travel is found to exceed nine inches.

28. BRAKE CYLINDERS AND TRIPLE VALVES.— These must be examined, cleaned and lubricated at least once every six months. A record must be kept of the dates of last cleaning and lubrication of these parts for each locomotive.

29. DRAINING.— The main reservoir, and also the drain cup in the train pipe under the tender, must be drained of any accumulation after each trip. The auxiliary reservoirs and triple valves must also be drained frequently, and daily in cold weather, and the train pipe under the engine and tender blown out.

30. AIR SIGNAL.— The train air signal apparatus must be examined and tested by suitable appliances from both the head of the engine and the rear of the tender, to know that the whistle responds properly. A

pressure gauge must be applied to the air signal pipe once each month, and oftener if found to be necessary, to ascertain that the reducing valve maintains the authorized pressure per square inch in the train signal pipe.

E.—INSTRUCTIONS TO INSPECTORS.

31. GENERAL.—It is the duty of all inspectors to see that the couplings, the pipe joints, the triple valves, the high speed reducing valve, the conductor's valves, the air signal valves, and all other parts of the brake and signal apparatus are in good order, of standard size for the car and free from leaks. For this purpose they must be tested under the full air pressure as used in service. No passenger train must be allowed to leave a terminal station with the brake upon any car cut out, or in a defective condition, without special orders from the proper officer.

If a defect is discovered in the brake apparatus of a freight car, which can not be held long enough to give time to correct such defect, the brake must be cut out and the car properly carded, to call the attention of the next inspector to the repairs required.

Special rules will specify the smallest proportion of freight cars, with the air brakes in good condition, which may be used in operating the train as an air brake train.

32. MAKING UP TRAINS AND TESTING BRAKES.—In making up trains, the couplings must be united and the cocks at the ends of the cars all opened, except at the rear end of the last car, where the cocks must be closed; the inspector must know that the air is passing through the pipes to the rear end, and the couplings properly hung up to the dummy couplings if so equipped. After the train is fully charged the engineman must be requested to apply the brakes. When the brakes have been applied, they must be examined upon each car to see that they are applied with proper piston travel. This having been ascertained, the inspector must signal the engineman to release the brakes. (In testing passenger brakes the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.) He must then again examine the brakes upon each car to note that all have released. If any defect is discovered, it must be corrected and the testing of the brakes repeated, until they are found to work properly. The inspector must then inform both the engineman and conductor of the number of cars with brakes in good order.

This examination must be repeated if any change is made in the make-up of the train before starting.

HIGH SPEED REDUCING VALVES ON LOCOMOTIVES AND TENDERS must be tested at least once every month, and adjusted to authorized pressure, if necessary, and cleaned and lubricated at least once in three months, and oftner if tests show that same is necessary.

33. CLEANING CYLINDERS AND TRIPLE VALVES.— The brake cylinders and triple valves must be kept clean and free from gum. They must be cleaned and lubricated as often as once in six months upon passenger cars, and once in twelve months upon freight cars. The dates of the last cleaning and lubrication must be marked with white paint on the cylinder or reservoir, in the space left opposite the words:

Cylinder, cleaned and lubricated.....
Triple, cleaned and lubricated.....

The triple valves and auxiliary reservoirs must be frequently drained, especially in cold weather, by removing the plug in the bottom of the triple valve and opening the bleed cock in the reservoir.

34. GRADUATING SPRINGS.— The graduating springs in the Westinghouse quick-action freight triple valves are .049 inch in diameter, nickeled-steel wire, 16 coils, 2¾ inches free height, 29-64 inch inside diameter, and in passenger .08 inch diameter, nickeled-steel wire, 13¼ coils, 2⅝ inches free height, 29-64 inch inside diameter. The graduating springs used in the Westinghouse plain triple valve in locomotive service are made of phosphor-bronze wire, .083 inch in diameter, 12 coils, 2½ inches free height, 25-64 inch inside diameter.

35. ADJUSTMENT OF BRAKES.— The slack of the brake shoes must be taken up by means of the dead truck levers.

In taking up such slack it must be first ascertained that the hand brakes are off, and the slack is all taken out of the upper connections, so that the truck levers do not go back within one inch of the truck timber or other stop, when the piston of the brake cylinder is fully back at the release position. When under a full application the brake piston travel is found to exceed nine inches upon passenger or freight cars, the brake shoe slack must be taken up and the adjustment so made that the piston shall travel not less than six inches. In taking up the brake shoe slack it must never be taken up by hand brakes. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

36. BRAKING POWER.— Where the cylinder lever has more than one hole at the outer end the different holes are for use upon cars of different weights.

It must be carefully ascertained that the rods are connected to the proper holes, so that the correct braking power shall be exerted upon each car.

37. REPAIR PARTS.— Inspectors must keep constantly on hand for repairs a supply of all parts of the brake and signal equipment that are liable to get out of order.

38. HANGING UP HOSE.— Inspectors must see that, when cars are being switched or standing in the yard, the hose is coupled between the cars or properly secured in the dummy couplings, when cars are so equipped.

39. RESPONSIBILITY OF INSPECTORS.— Inspectors will be held strictly responsible for the good condition of all the brake and signal apparatus upon cars placed in trains at their stations; they will also make any examination of brake apparatus or repairs to the same which they may be called upon to do by trainmen.

GENERAL QUESTIONS REGARDING THE USE OF THE AIR BRAKE AND TRAIN AIR SIGNAL.

GENERAL.

(All parties who have to do with the use, adjustment, care or repairs of air brakes should be thoroughly examined on these questions, in addition to the special questions for each class of men following them.)

1. Question. What is an air brake?

Answer. It is a brake applied by compressed air.

2. Q. How is the air compressed?

A. By an air pump on the locomotive.

3. Q. How does the compressed air apply the brakes?

A. It is admitted into a brake cylinder on each car, and it pushes out a piston in that cylinder, which pulls the brake on.

4. Q. How does the piston get back when the brakes are released?

A. There is a spring around the piston rod which is compressed when the brakes are applied, and when the air is allowed to escape to release the brakes, this spring reacts and pushes the piston in again.

5. Q. Where is the compressed air kept ready for use in the automatic air brake?

A. In the main reservoir on the locomotive, in the smaller or auxiliary reservoir on each car, and in the train pipe.

6. Q. Where does the compressed air come from directly that enters into the brake cylinder when the automatic brake is applied?

A. It comes from the auxiliary reservoir on each car in service application, and from the auxiliary reservoir and train pipe in emergency application.

7. Q. How does it get into the auxiliary reservoir?

A. It is furnished from the main reservoir on the locomotive through the train pipe and triple valve when the brakes are released.

8. Q. How is the automatic brake applied and released?

A. The automatic brake is applied by reducing the air pressure in the train pipe below that in the auxiliary reservoir, and is released by raising the train pipe pressure above that remaining in the auxiliary reservoir.

9. Q. Why does the compressed air not enter directly into the brake cylinder from the train pipe?

A. Because the triple valve used with the automatic brake prevents the air from entering directly from the train pipe to the brake cylinder when the pressure in the train pipe is maintained or increased.

10. Q. What other uses has the triple valve ?

A. It causes the brake cylinder to be opened to the atmosphere under each car, to release the brakes when the pressure in the train pipe is made greater than that in the auxiliary reservoir, and it opens communication from the train pipe to the auxiliary reservoir by the same movement; when the pressure in the train pipe is reduced it closes the openings from the train pipe to the auxiliary reservoir and from the brake cylinder to the atmosphere, and then opens the passage between the auxiliary reservoir and the brake cylinder by the same movement, so as to admit the air and apply the brakes.

11. Q. How many forms of triple valves are there in use, and what are they called?

A. Two; the plain triple and the quick-action triple.

12. Q. How can you tell the plain triple from the quick-action triple?

A. The plain triple has a four-way cock in it, with a handle for operating the cock; the quick-action triple has no such cock in it, but there is a plug cock in the cross-over pipe leading from the train pipe to the triple, when the quick-action triple is used.

13. Q. What are these cocks for in both cases?

A. They are to be used to cut out brakes on one car, without interfering with other brakes on the train, if the brake on that car has become disabled.

14. Q. How does the cock handle stand in the plain triple when the pipe is open for automatic action?

A. It stands in a horizontal position.

15. Q. In what position does the same handle stand when the brakes are cut out by closing the cock?

A. It stands at an inclined position midway between horizontal and vertical.

16. Q. How does the handle in the plug cock in the cross-over pipe, used with the quick action triple, stand for automatic action?

A. It stands with the handle crosswise with the pipe, and groove in plug lengthwise when cock is open.

17. Q. How does the handle and groove stand when the cock is closed and brake cut out of action?

A. It stands with the handle lengthwise of cross-over pipe, and the groove crosswise when closed.

18. Q. How is the train pipe coupled up between the cars?

A. By means of a rubber hose on each end of the train pipe, fitted with a coupling at the loose end.

19. Q. How is the train pipe closed at the rear end of train?

A. By closing the cock in the train pipe at the rear end of last car.

20. Q. How many such train pipe cocks are there to a car, on the air brake train pipe and on the air signal train pipe, and why?

A. Two for each pipe on each car, because either end of any car may sometimes be at the rear end of the train.

21. Q. How many kinds of train pipe cocks are there in use at the ends of the cars?

A. Two.

22. Q. Describe each and give the position of the handle and groove for open and closed in each case.

A. The older form of train pipe cock is a straight plug cock in the train pipe, not far from the hose connection; the handle stands crosswise with the pipe when it is open, and lengthwise with the pipe when closed; it is now found principally on the air signal pipe. The other form of train pipe cock now used on the air brake pipe is an angle cock placed at the end of the train pipe and close to the hose. The handle of the angle cock stands lengthwise with the pipe when open, and crosswise with the pipe when closed. The groove is also a guide to tell whether open or closed.

23. Q. What uses have these train pipe cocks besides to close the pipe at the end of the train?

A. They are used to close the train pipe at both sides of any hose coupling which is to be parted, as when the train is cut in two.

24. Q. Why is it necessary to close the train pipe on both sides of the hose coupling before it is parted?

A. To prevent the escape of air from the train pipe, which would apply the brakes.

25. Q. How must the hose coupling be parted when it is necessary to do so, and why?

A. The air brake must first be released on the train from the locomotive, then the adjacent train pipe cocks must both be closed and the coupling must be parted by hand, to prevent the possibility of injury to the rubber gasket in the coupling.

26. Q. Why must the brakes be fully released before uncoupling the hose between the cars?

A. Because if the brakes are applied upon a detached car they can not be released without bleeding the auxiliary reservoir.

27. Q. In coupling or uncoupling the hose between cars, what must be done if there is ice on the couplings?

A. The ice must first be removed and the couplings thawed out, so as to prevent injury to the rubber gaskets in uncoupling, and to insure tight joints in coupling the hose.

28. Q. What must be done with a hose coupling which is not coupled up, such as the rear hose of a train, or any hose on a car which is standing or running, but not in use?

A. It must be placed in the dummy coupling if provided for in such manner that the flat pad on the dummy will close the opening in the coupling.

29. Q. What pressure should be carried in the train pipe and auxiliary reservoir?

A. The authorized pressure, as per special instructions.

30. Q. Why should the authorized pressure be maintained?

A. Because this pressure is necessary to get the full braking force which each car is capable of using, and, if it be exceeded, there will be danger of sliding the wheels.

31. Q. How much pressure can be obtained in the brake cylinder by the service application of the brakes with seventy pounds in the auxiliary reservoir?

A. About fifty pounds to the square inch, with an 8-inch piston travel.

32. Q. Why can only fifty pounds pressure be obtained under these circumstances?

A. Because the air at seventy pounds pressure in the auxiliary reservoir expands into an additional space when the auxiliary reservoir is opened to the brake cylinder, and when the pressure has become equalized it is thus reduced to fifty pounds.

33. Q. How much must the train pipe pressure be reduced, in order to get fifty pounds pressure in the brake cylinder, in ordinary service?

A. Twenty pounds.

34. Q. Can the brakes be applied so as to get only a portion of this fifty pounds pressure in the brake cylinder, and how?

A. They can be so applied by reducing the train pipe pressure less than twenty pounds.

35. Q. If the train pipe pressure be reduced ten pounds, what will be the pressure in the brake cylinder?

A. About twenty-five pounds.

36. Q. How is this graduated action obtained?

A. By means of the graduating valve in the triple valve.

37. Q. Is it important to keep all the air brake apparatus tight and free from leaks?

A. Yes.

38. Q. Why is this important?

A. In order to get full service from the air brakes, and to prevent the waste of air, and also to prevent the brakes applying automatically by reason of leak in the train pipe.

39. Q. Is it important to know that the train pipe is open throughout the train and closed at the rear end before starting out?

A. Yes, this is very important.

40. Q. Why is this very important?

A. Because if any cock in the train pipe were closed, all the brakes back of the cock which is closed would be prevented from working.

41. Q. How can you ascertain that the train pipe cocks are all open when the train is made up?

A. By testing the brakes; that is, by applying and releasing them, and observing whether they all operate.

42. Q. Do you understand that no excuse will be acceptable for starting out the train without first testing the air brakes?

A. Yes.

43. Q. Why is this rule absolute?

A. Because the safety of passengers and of property depends upon the brakes being properly coupled up and in an operating condition before the train is started.

44. Q. At what other times should the brakes be tested?

A. After each change in the make-up of the train and before starting the train down certain designated grades.

45. Q. From where does the air signal apparatus receive its pressure?

A. From the main air reservoir through the reducing valve.

46. Q. How much air pressure should be carried in the air signal train pipe?

A. The authorized pressure.

47. Q. Is it important that this train pipe and its connections be also kept tight?

A. Yes.

48. Q. After taking up the slack of the brake shoes, how far should the brake piston travel in the cylinders on cars and tenders with a full application of the brake?

A. Not less than six inches, nor more than nine inches.

49. Q. What would happen if the piston traveled less than six inches when brakes are fully applied?

A. A partial application of the brakes might not force the piston beyond the leakage groove in the brake cylinder provided for the escape of small amounts of air.

50. Q. Why should the piston travel not be permitted to exceed nine inches on passenger cars, tenders, or freight cars?

A. Because if it travels farther than this when sent out, a little wear of the brake shoes will cause the piston to travel far enough to rest against the back cylinder head when the brakes are applied, and this cylinder head would then take the pressure instead of its being brought upon the brake shoes.

51. Q. How far should the driver brake piston travel with a full application of the brakes, and why?

A. Not less than two inches nor more than three and one-half inches for the cam type of brake, and from four to six inches for other forms.

52. Q. If the brakes stick upon any car so that the engineman can not release them at any time, how should they be released?

A. By opening the release cock in the auxiliary reservoir and holding it open until air begins to escape from the triple valve, and then closing it again.

53. Q. What is the pressure retaining valve, and what is its use?

A. The pressure retaining valve is a small valve placed at the end of a pipe from the triple valve, through which the exhaust takes place from the brake cylinder. It is used to retard the brake release on heavy grades, and holds the brakes partially applied, so as to allow more time for the engineman to recharge the auxiliary reservoir.

54. Q. What precautions are necessary on every train in regard to hose couplings?

A. Every train must carry at least two extra hose and couplings complete, for use in replacing any hose couplings which may fail or become disabled. These extra hose and couplings to be carried on such part of the train as is required by the rules and regulations.

SPECIAL FOR ENGINEMEN.

55. Q. How should the air pump be started?

A. It should be started slowly, so as to allow the condensation to escape from the steam cylinder and prevent pounding, which is more likely to occur when the air pressure is low.

56. Q. Why should the piston rod on the air pump be kept thoroughly packed?

A. To prevent the waste of air and steam.

57. Q. How should the steam cylinder of the air pump be oiled, and what kind of oil should be used?

A. It should be oiled as little as necessary through a sight-feed lubricator, and cylinder oil should be used.

58. Q. How should the air cylinder of the air pump be oiled; what kind of oil?

A. It should be supplied with valve oil as often as necessary, through a cup provided for that purpose. Also, a well saturated swab should be kept on the piston rod. Lard oil, and other animal or vegetable oils should not be used, as their use causes the brake valve and the triple valves to gum up. The oil must never be introduced through the air inlet ports, as this practice would cause the pump valves to gum up.

59. Q. What regulates the train pipe pressure?

A. The train pipe governor, or feed valve, provided for that purpose.

60. Q. Why should the authorized pressure be carried in train pipe?

A. Because this pressure produces the strongest safe pressure of the brake shoes upon the wheels. A higher train pipe pressure is liable to cause the wheels to slide.

61. Q. What does the feed valve attachment on the brake valve accomplish?

A. When properly adjusted it restricts the train pipe pressure to the authorized amount, with the brake valve handle carried in running position.

62. Q. How often should the brake valve be thoroughly cleaned and oiled?

A. At least once every two months.

63. Q. If the main valve in the brake valve is unseated by dirt or by wear, what may be the result, and what should be done?

A. It may be impossible to get the excess pressure; when the brakes have been applied they may keep applying harder until full on, or when they have been applied they may release. The main valve should be thoroughly cleaned, and if worn it should be faced to a seat.

64. Q. If the piston in the brake valve becomes gummed up or corroded from neglect to clean it, what will be the result?

A. It will be necessary to make a large reduction of pressure through the preliminary exhaust port before the brakes will apply at all, and then the brakes will go on too hard and will have to be released.

65. Q. How and why should the train pipe under the tender always be blown out thoroughly before connecting up to the train?

A. By opening the angle cock at the rear end of the tender and allowing the air from the main reservoir to blow through. This blows out the oil, water, scale, etc., which may accumulate in the pipe, and which would be blown back into the train pipe and triple valves if not removed before coupling to the train.

66. Q. When the locomotive is coupled to the train, why is it necessary to have excess pressure in the main reservoir?

A. So that the brakes will all be released and the train quickly charged when the engineman's valve is placed in the release position.

67. Q. Why should the driver brakes be operated automatically with the train brake?

A. Because it adds greatly to the braking force of the train, and the brakes can be applied alike to all the wheels for ordinary stops, and in an emergency the greatest possible braking force is at once obtained by one movement of the handle.

68. Q. In making a service application of the brakes, how much

reduction of the train pipe pressure from seventy pounds does it require to get the brakes full on?

A. About twenty-five pounds reduction.

69. Q. What should the first reduction be in such an application?

A. Not less than five pounds, so as to insure moving the pistons in the brake cylinders past the leakage grooves.

70. Q. What is the result of making a greater reduction of pressure than twenty-five pounds?

A. A waste of air in the train pipe, without getting any more braking force, and therefore requiring more air to release the brakes.

71. Q. How many applications of the brakes are necessary in making a stop?

A. One or two applications.

72. Q. Why is it dangerous to apply and release the brakes repeatedly in making stops?

A. Because every time the brakes are released the air in the brake cylinders is thrown away, and if it is necessary to apply them again before sufficient time has elapsed to recharge the auxiliary reservoirs the application of the brakes will be weak, and after a few such applications the brakes are almost useless on account of the air having been exhausted from the auxiliary reservoirs.

73. Q. In releasing and recharging the train, how long should the handle of the brake valve be left in the release position?

A. Until the train pipe pressure has risen nearly to authorized pressure.

74. Q. In making service stops with passenger trains, why should you release the brakes just before coming to a full stop?

A. So as to prevent stopping with a lurch; it also requires less time for the full release of the brakes after stopping.

75. Q. In making stops with freight trains, why should the brakes not be released until after the train has come to a full stop?

A. Because long freight trains are apt to be parted by releasing the brakes before rear brakes are fully released.

76. Q. In making service stops, why must the handle of the brake valve not be moved past the position for service applications?

A. So as to prevent unnecessary jerks to the train and the emergency action of the triple valve when not necessary.

77. Q. If you find the train dragging from the failure of the brakes to release, how can you release them?

A. By placing the handle of the brake valve in full release position for a few seconds and returning it to the running position, if the train pipe pressure is not up to the authorized amount; but if maximum pressure is in train pipe, the brakes should be applied with from five to ten pounds

reduction, according to the length of train pipe, and released in the usual manner.

78. Q. When the brakes go on suddenly when not operated by the brake valve, and the gauge pointer falls back, what is the cause, and what should you do?

A. Either a hose has burst, or a conductor's valve has been opened, or the train has parted. In any event, the engine throttle should be closed and the handle of the brake valve should immediately be placed on lap position to prevent escape of air from main reservoir.

79. Q. Are the brakes liable to stick after an emergency application, and why?

A. The brakes are harder to release after an emergency application because they are on with full force and it requires higher pressure than usual in the train pipe to release them again. In this case it is necessary always to have in reserve the excess pressure of the main reservoir to aid in releasing the brakes. With the quick-action triple valve this is especially necessary, because air from the train pipe as well as from the auxiliary reservoir is forced into the brake cylinder when a quick application of the brake is made, thus increasing the pressure in the brake cylinder without the usual reduction of pressure in the auxiliary reservoir, and requiring a correspondingly high pressure in the train pipe afterward to cause the brakes to be released.

80. Q. In using the brakes to steady the train while descending grades, why should the air pump throttle be kept well open?

A. So that the pump may quickly accumulate a full pressure in the main reservoir for use in recharging the train pipe and auxiliary reservoir when the brakes have been released again.

81. Q. In descending a grade, how can you best keep the train under control?

A. First, by commencing the application of the brakes early, so as to prevent too high a speed being reached; secondly, by making an initial reduction that will lightly apply all brakes in the train, and by slowing the train down just before it is necessary to charge the auxiliary reservoir, so as to give time enough to refill same before much speed is again attained.

82. Q. If the train is being drawn by two or more locomotives, upon which locomotives should the brakes be controlled, and what must the engineman of the other locomotive do?

A. The brakes must be controlled by the leading locomotive, and the enginemen of the following locomotives must close the cock in the train pipe just below the brake valves. The latter must always keep the pump running and in order, and main reservoir charged with pressure, with the brake valve in the running position, so that he may quickly operate the brakes if called upon to do so.

83. Q. If the air signal whistle gives only a weak blast, what is the probable cause?

A. Either the reducing valve is out of order so that the pressure is considerably less than forty pounds, or the whistle itself is filled with dirt or not properly adjusted, or the port under the end of signal valve is partly closed by gum or dirt.

84. Q. If the reducing valve for the air signal is allowed to become clogged up with dirt, what will the result probably be?

A. The signal pipe might get the full main reservoir pressure, and the whistle will blow when the brakes are released.

85. Q. If you discover any defect in the air brake or signal apparatus while on the road, what must be done?

A. If it is something that can not be readily remedied at once, it must be reported to the Enginehouse Foreman as soon as the run is completed.

86. Q. What is the result if water be allowed to collect in the main reservoir of the brake apparatus?

A. The room taken up by the water reduces the capacity for holding air, and the brakes are more liable to stick. In cold weather also the water may freeze and prevent the brakes from working properly.

SPECIAL FOR ENGINE REPAIRMEN.

87. Q. How often must the air brake and signal apparatus on locomotives be examined?

A. After each trip.

88. Q. Under what pressure must it be examined?

A. Under full pressure.

89. Q. Should the train pipe pressure exceed the maximum, where would you look for the cause of the trouble?

A. In the devices controlling train pipe pressure.

90. Q. How often must the main reservoir and the drain cup under the tender be drained?

A. After each trip.

91. Q. How often must the triple valves and the cylinders of the driver and tender brakes be cleaned and lubricated?

A. They must be thoroughly cleaned and lubricated once every six months. If the driver brake cylinders are so located that they become hot from the boiler, they may acquire lubrication more frequently.

92. Q. If there are any leaks in the pipe joints or anywhere in the apparatus, what must you do?

A. Repair them before the locomotive goes out.

93. Q. How is the brake shoe slack of the cam driver brake taken up, and what precautions are necessary?

A. By means of the cam screws, and it is necessary to lengthen both alike, so that when the brake is applied the point of contact with the cams will be in a line with the piston rod.

94. Q. How is the brake shoe slack of driver brakes on a locomotive with more than two pairs of driving wheels taken up?

A. By means of a turnbuckle or screw in the connecting rods.

95. Q. How is the slack of the tender brake shoes taken up?

A. By means of the dead truck levers; if they will not take it up enough, it must be taken up in the underneath connection, and then adjusted by the dead lever.

96. Q. How far should the driver brake piston travel in applying the brakes?

A. Not less than two inches, nor more than three and one-half inches with the cam type of brake, and from four to six inches with other forms.

97. Q. What travel of piston should the tender brakes be adjusted for?

A. Not less than two inches, nor more than three and one-half inches with the cam type of brake, and from four to six inches with other eight inches.

SPECIAL FOR TRAINMEN.

98. Q. How should you proceed to test the air brakes before starting out, after a change in the make-up of a train, or before descending certain specially designated grades?

A. After the train has been fully charged with air, the engineman must be required to apply the brakes; when he has done so the brakes must be examined upon each car to see that the air is applied and that the piston travel is not less than six nor more than nine inches. The engineman must then be required to release the brakes; after he has done so, each brake must be examined again to see that all are released. The engineman and conductor must then be notified that the brakes are all right, if they are found so. (In testing passenger brakes, the American Railway Association train air signal whistle code for applying or releasing must be used, one of which signals must be given from the discharge valve on the rear car.)

99. Q. In starting out a passenger train from an inspection point, how many cars must have the brakes in service?

A. Every car in the train.

100. Q. When might you cut out a brake upon a passenger car?

A. Never, unless it gets out of order while on the run, in which

case it must be reported to the inspector at the end of the run, or upon the first opportunity which may give sufficient time to repair it.

101. Q. If a hose bursts upon the run what must be done, if the train is in a safe place?

A. The hose must first be replaced by a good one, and the engineman then signaled to release the brakes. The train must not proceed until the brakes have been reconnected and tested upon the train to see that all are working properly.

102. Q. If the train is not in a safe place when the hose bursts, what must be done?

A. The train pipe cock immediately ahead of the burst hose must be closed and the engineman signaled to release the brakes. The brakes at the rear of the burst hose must then be released by bleeding the auxiliary reservoirs, and the train must then proceed to a safe place to replace the hose and connect up the brakes, after which the brakes must be tested.

103. Q. If the train breaks in two, what must be done?

A. The cock in the train pipe at the rear end of the first section must be closed and the engineman signaled to release the brakes. The two parts of the train must then be coupled, the hose connected and the brakes again released by the engineman. When it is ascertained that the brakes are all released, the train may proceed.

104. Q. Explain how the pressure-retaining valves are thrown into action or thrown out of action, and when this must be done.

A. The pressure-retaining valve is thrown into action by turning the handle of the valve to a horizontal position, and it is thrown out of action again by placing this handle in a vertical position pointing downward. This handle should be placed in a horizontal position at the top of a heavy grade, and it should always be returned to a vertical position at the foot of the grade, as otherwise the brakes will drag on any cars which still have the handle of the pressure-retaining valve in the horizontal position.

105. Q. If the brake of any car is found to be defective on the run, how should you proceed to cut it out?

A. By closing the cock in the cross-over pipe of the quick-action brake, or in the triple valve of the plain automatic brake, and then opening the release cock in the auxiliary reservoir upon that car, leaving it open, if a passenger car, or holding it open until all the air has escaped from it, if a freight car.

106. Q. When it is necessary to cut out a defective brake upon a car, why should it always be cut out at the triple valve and never by the train-pipe cock at the end of the car, even if it is the last car of the train?

A. The train pipe should always be open from the locomotive to the rear end of the last car, so that if the train breaks in two the brakes will be automatically applied before the parts of the train have separated sufficiently to permit damage to be done by their coming together again,

and so that the brakes may be applied with the conductor's valve upon any car.

107. Q. Should the train pipe burst under any car, what must be done?

A. The train must proceed to the nearest switching point, using the brakes upon the cars ahead of the one with the burst pipe, where the car with the burst pipe must be switched to the rear of the train; the hose must then be coupled up to the rear car and the cock at the rear end of the next to the last car opened, and the cock at the forward end of the last car closed, so that if the train should part between the last two cars the brakes will be applied.

108. Q. What is the conductor's valve, and what is its use?

A. It is a valve at the end of a pipe leading from the train-brake pipe upon each passenger car; it is to be opened from the car in any emergency when it is necessary to stop the train quickly, and only then. When used it should be held open until the train is stopped, and then it should be closed.

109. Q. What is the air signal for, and how is it operated?

A. It is to signal the engineman, in place of the old gong signal, and it is operated by pulling directly downward on the cord for one second and releasing immediately, allowing three full seconds to elapse between pulls.

110. Q. If the discharge valve on the air-signal system is out of order or leaking on any car, how can you cut it out?

A. By closing the cock in the branch pipe leading from the train-signal pipe to the discharge valve; to do so the handle of this cock should be placed lengthwise with the pipe.

111. Q. How is the slack taken up so as to secure the proper adjustment of piston travel?

A. By means of the dead-truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead-truck lever. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

SPECIAL FOR INSPECTORS.

112. Q. Do you understand that no passenger train may be started out with any of the brakes cut out of service?

A. I do.

113. Q. Why is it important that no leaks should exist in the air brake service?

A. Because they would interfere with the proper working of the brakes and might cause serious damage.

114. Q. What must be done with the air brake or air-signal couplings when not united to other couplings, on cars equipped with dummy couplings?

A. They must be secured in the dummy coupling, so that the face of the dummy coupling will cover the opening of the hose coupling so as to prevent dust and dirt from entering the hose.

115. Q. If the air issues from the exhaust port of the quick-action triple valve when the brakes are off, what is the cause?

A. It is probably due to dirt on the rubber seated emergency valve.

116. Q. How often must the cylinder and triple valves be examined, cleaned and lubricated?

A. As often as once every six months on passenger cars and once in twelve months on freight cars. The dates of the last cleaning and lubrication must be marked with white paint on the cylinders.

117. Q. What is the difference between the quick-action passenger and freight triple valve?

A. The passenger triple valves have larger ports and slide valves.

118. Q. How may a passenger triple valve be distinguished?

A. By having one exhaust outlet, or suitable lettering designating the class of service.

119. Q. How may a freight triple valve be distinguished?

A. By its two exhaust outlets, one being plugged.

120. Q. When should the graduating spring of the triple valve be replaced with a new one?

A. When it is worn or rusted out, or not of standard size.

121. Q. To what travel of piston must the brakes be adjusted?

A. Not less than six inches, and this adjustment must be made whenever the piston travel is found to exceed nine inches.

122. Q. How is the slack taken up so as to secure this adjustment?

A. By means of the dead-truck lever, and if that is not sufficient, one or more holes must be taken up in the underneath connection and the adjustment then made by the dead-truck lever. Where automatic slack adjusters are applied to any car, such adjuster must be fully released before the slack is taken up elsewhere.

123. Q. What are the different holes in the outer end of the cylinder levers for, and why must the connections be pinned to the proper hole for each car?

A. These holes are to enable the adjustment of the brake pressure to be made according to the weights of the different cars. The connection must be made to the proper hole in each case, according to the weight of the car, so as to give proper braking power, otherwise the brake will be inefficient, or the wheels may be slid under the cars.

124. Q. How many sizes of high speed brake-reducing valves are there in use, and how will it be known to which size of cylinders they should be connected?

A. There are three sizes, namely, one for 8-inch, one for 10-inch and 12-inch, and a third for 14-inch and 16-inch cylinders, and they can be distinguished by the raised figures cast on their body.

125. Q. To what pressure must the high speed brake-reducing valve be adjusted on passenger equipment cars?

A. The authorized pressure.

CODE OF APPRENTICESHIP RULES.

At the convention of 1898 the following code of rules was adopted as the Recommendation of the Association:

Code of Apprenticeship Rules.

1. A regular apprentice is one who has had no previous shop experience and is not a graduate of a technical institution.

2. No regular apprentice shall be taken into the shop below the age of fifteen or after the age of nineteen years.

3. No apprentice shall be taken into the shop who has not received the elements of a common education, and who does not give evidence of such capacity as to promise the ability to become a competent mechanic.

4. No apprentice shall be taken into the shop without the consent of his parents or lawful guardians, who shall have a thorough understanding of the conditions of such apprenticeship, and who shall execute such documents, including a release of the company from liability for accidents to the said apprentice, as the company may require.

5. The term during which an apprentice shall serve before receiving a certificate of apprenticeship shall not be less than three years, nor more than five years.

6. There shall be a regular apprentice course framed for each shop, which course each apprentice shall go through during his term, the time to be spent on each class of work being defined, and such definition shall be observed as closely as practicable with due regard to the capacities and condition of the individual apprentice.

7. During the term of the apprenticeship a careful and proper record shall be kept of the work and progress of the apprentice, and also of the general behavior and conduct, which record shall be entered on properly authorized blanks or books provided for the purpose not less frequently than once every week during such term.

8. Each apprentice shall be paid for the work done by him upon a scale duly agreed on and provided for in advance.

9. Under no circumstances shall the company assume any liability for the employment of an apprentice after the conclusion of his term.

10. On the conclusion of the term of apprenticeship, each apprentice shall be given a certificate in a proper form, duly signed by the proper officer of the company, which shall set forth the length of time which each apprentice has served and the work on which he has been engaged, as well as some indication of his general behavior during his term.

11. Apprentices who have already served part of a term in other shops, or who have taken part of a course at a recognized technical institution, may be received under such modifications of the foregoing rules as may be deemed proper.

Recommendations Supplementary to the Code of Apprenticeship Rules.

RULE 3. An apprentice should be able to read and write, and have a knowledge of arithmetic. Some companies insist that a candidate shall have reached a point in his studies equivalent to that of the eighth grade of the public schools. This standard, where applicable, will be found satisfactory.

RULE 4. The following is a blank form of release which is recommended as satisfactory:

APPENDIX "C."

(Form for Release of Minors.)

WHEREAS, The A. B. C. Railroad Company has agreed to take into its service .....
a minor, subject to discharge at the pleasure of the company, and has agreed with our consent to pay him the compensation to be earned for his services, and has been authorized to take from him such receipts and acquittances as the said company may require;

AND WHEREAS, The said .....
by reason of such employment, will be subjected to great risk of personal injury from neglect of other employes, agents and officers of the said company, and from defects of machinery, and from other causes;

AND WHEREAS, In the event of injuries to the said.....
....., whether resulting fatally or otherwise, the said.....
or members of his family might make claims for damages against the said company;

NOW, IN ORDER to release the said company from all claims or liability for damages for injuries of any and all kinds, from any cause whatsoever, ...the father, and .....the mother, in their several and individual capacities, and acting as guardian for the said ....., and the said .....himself, in consideration of the employment by the said railroad company of the said .....in the service of the said company, and in consideration of the sum of one dollar now in hand paid by the said company, do hereby release and forever discharge the A. B. C. Railroad Company for all claims for damages, and do also further agree to release the said company from all claims and liability for damages arising out of any injury or injuries to the said.....
.....resulting from the

character of his employment, from the negligence of other employes, or agents or officers of the said company, from defects of machinery or any other cause or causes whatsoever, whilst a minor and whilst in the service of the said company in any capacity whatsoever.

WITNESS our hands and seals this.....day of.....18....

.....[SEAL]

WITNESSES: .....[SEAL]

....[SEAL]

....[SEAL]

....[SEAL]

RULE 5. Four (4) years is recommended as the best standard term. Whenever possible this should be adopted. The limits given in the rule, "not less than three nor more than five years," are made sufficiently wide to cover all special cases. The brightest and most ambitious boy should not be permitted to complete his course in less than three years under any circumstances. A boy who does not complete it in five years had better be something else than a mechanic.

RULE 6. The following courses are recommended for the various shops:

Machine Shop.

TOOL ROOM.— General use of tools, names, etc., work on small planer, drilling machine, shaper and lathes, provide tools; six months to actually serve.

ERECTING SHOP.— Helping on general work — gang No. 1, one month; helping on general work — gang No. 2, one month; helping on general work — gang No. 3, one month.

MACHINE SHOP.— General instructions, milling machine, boring mill, horizontal machine, axle lathe, and helping in general; three months to actually serve.

Boring, driving and truck brasses and quartering machine; two months.

Cylinder boring machine and planer: one month.

Rod: Rod gang, three months; small lathe (alone), two months; large slotter, one month; brass lathe, two months; small planer, one month; large and small planers, two months; driving wheel lathe, one month; large lathe (alone), two months; motion work lathe, one month; general vise work, three months; surface table, three months.

ERECTING SHOP.— General work — gang No. 1, five months; general work — gang No. 2, three months; general work — gang No. 3, four months.

Total number of months' actual service — forty-eight.

Your committee submits this as a basis for an adequate course of training in the machine shop, with the distinct understanding that it is to be qualified so far as the term of service to be spent in the different items, and also in the whole course, by the quality and capacity of the individual boys, under the discretion of whoever has them in charge.

Blacksmith Shop Course.

1. To start the apprentice on a bolt machine for six months. Here he will learn the rudiments of heating iron; also the setting and adjusting of dies, and at the same time by observation will learn the names of the tools and their use in that portion of the shop.

2. The next six months in operating a steam hammer. In this position he has a good opportunity to note how the blacksmiths handle and form iron; at the same time require him to help at the fires in the immediate vicinity of the hammer.

3. The next six months should be as a helper on a small fire, with a man who is quick and handy with light work.

4. The next six months on a light fire without a helper, where he will learn to handle the hand hammer.

5. For the next three months give him a light fire with a helper; the fire should be so located that he will be called upon to assist in taking heats for the larger fires.

6. For the next six months on heavier work that does not require skill.

7. For the next three months put him helping at the tool-dressing fire, and if the shop has two tool-dressing fires, the next three months on the second tool-dressing fire.

8. The next twelve months put him on a heavy fire with as much of a variety of work as can be arranged.

Boiler Shop Course.

1. The first three months heating light rivets.

2. The next three months helping on the heavy sheet-iron work, such as wheel covers, ash pans, etc.

3. Three months holding on rivets for tank work.

4. Three months holding on rivets for boiler work.

5. Six months riveting on patches, chipping and calking on tank work.

6. Six months setting flues.

7. Six months patching and bracing boilers, chipping and calking and general riveting.

8. Six months blacksmithing, to learn how to make and fit braces, to dress necessary tools and assist in fitting up his work.

9. The fourth year to lay out flange and do general boiler work.

RULE 7. It is recommended that some one person be given direct charge of all apprentices and be held responsible for their proper instruction. He can be known as "the Foreman of Apprentices," or he can be designated to perform the duties, without special title, in conjunction with his ordinary work. The following blank page for an Apprentice Record Book is recommended:

APPRENTICE RECORD.

NAME.	WEEKS.																					TOTAL WEEKS WORKED.	AVERAGE CREDIT. CONDUCT AND ABILITY.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 up to 52 weeks									
John Doe	80	50	90	70	50	30	90	80	70	50	30	90	80	70	40	70	80	50	30			.....	63
James Smith	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			.....	.....
Chas. Jones	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...			.....	.....

RULE 8. The scale of pay must be governed largely by geographical and individual conditions. It is recommended that the rate of pay be 50 cents for a ten-hour day for the first year, with an increase of 25 cents a day for each year thereafter. For an eight-hour day 40 cents a day at the start and 20 cents a day increase yearly.

RULE 9. The following form of certificate is recommended:

APPENDIX "B."

(Form of Certificate of Apprenticeship.)

A. B. C. RAILROAD COMPANY,

MOTIVE POWER DEPARTMENT.

CERTIFICATE OF APPRENTICESHIP.

.....
has served an apprenticeship as.....
at the shops of this Company at.....
during the period from.....to.....
and has made.....hours time over 10 hours per day.

WORK ON WHICH EMPLOYED.

APPROXIMATE NO. OF MONTHS.	KIND OF WORK.
.....	.....
.....	.....
.....	.....

OFFICERS UNDER WHOM EMPLOYED.

NAME.	TITLE.
.....	.....
.....	.....
.....	.....

GENERAL RECORD OF APPRENTICE.

.....
.....

Supt. Motive Power.

RESOLUTIONS.

Revised and modified at convention, 1903.

At the convention of 1886 the following resolutions prevailed:

Resolved, That this Association deprecates the giving of testimonials or recommendatory letters for publication, and enjoins all to restrict matters of this nature to letters of inquiry. (See page 26, report 1886.)

Resolved, That it is the sense of this convention that in practice it is unnecessary to bead flues in the front end. (See page 152, report 1886.)

At the convention of 1888 the following resolution prevailed:

Resolved, That it is the sense of the Master Mechanics' Association that the pilots of all engines should have steps placed on the front end for the safety and convenience of brakemen while coupling at the front ends. (See page 162, report 1888.)

At the convention of 1893 the following resolution prevailed:

Resolved, That while the Master Mechanics' Association regards the water glass as a convenience and an additional precaution against low water, we do not regard it as an absolute necessity to the safe running of locomotives. (See page 161, report 1893.)

At the convention of 1896 the following resolutions prevailed:

Resolved, That it is the sense of this meeting that the radial stay boiler is as safe as the crown bar boiler, and that the former is easier to keep clean and more economical in repairs. (See page 280, report 1896.)

Resolved, That it is the sense of this Association that the statement of the performance of locomotives should be made on the basis of train load, in lieu of train miles or loaded car miles, as is the prevailing practice at present. (See page 333, report 1896.)

At the convention of 1899 the following resolutions prevailed:

Resolved, That it is the sense of this convention that the time has not arrived when we can abandon instructions to those who use the air brakes, but that the time has arrived when we should perhaps take more care to instruct those who repair the brakes and keep them in order. (See page 71, report 1899.)

Resolved, That it is the sense of the American Railway Master Mechanics' Association that the use of fusible plugs in the crown sheets of locomotive fire boxes is not conducive to the prevention of the overheating of the crown sheet. (See page 153, 1899 report.)

Resolved, That it is the sense of this Association that the ton-mile basis for motive power statistics is the most practical, and encourages economical methods of operating; and that it is desirable that the heads of motive power departments urge its adoption on their managements. (See page 173, report 1899.)

Resolved, That it is the sense of this Association that it is not advisable to use bars in exhaust nozzles. (See page 277, report 1899.)

At the convention of 1901 the following resolutions prevailed:

Resolved, That it is the sense of this Association that a strict comparison of motive power statistics, one road with another, will not secure the best results, but that such comparisons should be made with the records of the same division for preceding periods of time. (See page 79, report 1901.) (See modification, page 70, 1902 report.)

Resolved, That it is the sense of this Association that the ton-mileage of the locomotive is a just credit to the motive power department for statistical purposes. (See page 83, report 1901.) (See modification, page 77, 1902 report.)

Resolved, That it is the sense of this Association that it is necessary that the side rods should be on engines traveling from the works to the railroad they are built for. (See page 99, report 1901.)

At the convention of 1902 the following resolutions prevailed:

"*Resolved,* That it is the sense of this Association that conclusions based on a comparison of the statistics of one railroad with another may easily prove incorrect, should be given less weight than they usually are, are just only when the accompanying conditions are fairly well known and their influence can be determined with some degree of accuracy; that a comparison of the statistics of a division or a system with those of the same territory for a previous corresponding period very largely eliminates these uncertainties and makes conclusions based on such a comparison much more reliable."

"*Resolved,* That it is the sense of this Association that the ton-mileage of the locomotive and caboose is a just credit to the motive power department for statistical purpóses."

"*Resolved,* That the ton-mile is the best practical basis now available for motive power and operating statistics by which to judge the efficiency of locomotive and train service.

"*Resolved,* That actual tonnage should be used in computing ton-mile statistics for comparison with those of other roads, but for comparison with the previous records of the same system or division the use of adjusted tonnage is advisable.

"*Resolved,* That the statistics of passenger, freight, work train and switching services should be on the ton-mile basis, each service in a separate group, and passenger and freight service to be each further grouped under Through and Local.

"*Resolved,* That the statistics of branch lines and main lines should be kept separately.

"*Resolved,* That the credit of ton-mileage for locomotives in switching service should be proportional to their tractive power.

"*Resolved,* That the ton-mileage of trains using more than one locomotive should be divided among the locomotives attached to these trains in proportion to their tractive power and for the distance over which the helping locomotives are used.

"*Resolved,* That the tonnage of the locomotive should be its weight in working order, plus the light weight of the tender and half its capacity of coal and water."

At the convention of 1906 the following motion was adopted:

That twenty-four hours be adopted as the limit distinguishing between engines in service and those under repairs, and that $100 be adopted as the limit distinguishing between running and shop repairs.

Obituary.

RICHARD W. BUSHNELL

Was born in Norwich, Connecticut, August 10, 1830. After leaving school, possessing a natural aptitude for mechanics, he obtained a situation in the Rogers Locomotive Works, serving the usual period of apprenticeship, then went to Hartford for further instructions, and became most skilled in his profession. In 1853 he came to Chicago and entered the employ of the Chicago & Galena Railroad Company, where he remained until 1857,

having in the meantime held various positions on this road, and finally was promoted to superintendent of the shops at Harlem, Illinois, remaining there until the consolidation with the Chicago & North-Western Railway. In 1868 he removed to Chicago and took charge, as Master Mechanic, of the Galena Division of the Chicago & North-Western Railway, which posi-

tion he held four years. He then went to Cedar Rapids and took charge of the Machinery Department of the Burlington, Cedar Rapids & Northern Railway, remaining until 1901, at which time he retired from active service.

Mr. Bushnell was an untiring worker, was noted for strict integrity and sobriety, and for being strictly impartial in his dealings with the subordinate officers and the rank and file. He commanded the respect of the employees and all with whom he came in contact.

He was for years a prominent member of the Episcopal Church, also a Mason and Knight Templar, and was a member of the Master Car Builders' Association since 1882, and of the American Master Mechanics' Association, having joined it in 1870, proving his great interest in its work by his regular attendance.

The death of Mr. Bushnell was unexpected, he having retained his vigor until the time of the accident which caused his death. On June 2, 1906, he was ascending a ladder at his home, when he slipped and fell, dislocating his shoulder and receiving internal injuries which resulted in his death Wednesday evening, June 6.

He is survived by three sons and one daughter, and is mourned by many friends.

T. S. LLOYD.

L. M. BUTLER.

Mr. L. M. Butler was born at Hinsdale, New Hampshire, April 9, 1838, and died at Auburn, Rhode Island, May 14, 1905. He became a member of the American Railway Master Mechanics' Association in 1891.

He was a man who was highly respected by all who knew him.

He entered railroad service as engine-house foreman for the B. C. & F. R. R. Co. (now Taunton Division of the N. Y. N. H. & H. system), in April, 1871. He remained in this position until about 1882, when he accepted a position as engineer on the Rockville Branch of the New York & New England Railroad, now a portion of the Highland Division of that road. He retained that position until the spring of 1884, when he accepted a position as Master Mechanic of the Richmond Paper Company, located at Phillipsdale, Rhode Island. He remained there until the spring of 1885, when he resigned to accept a position as foreman of the erecting shop of the Rhode Island Locomotive Company, at Providence, Rhode Island. In April, 1886, he was appointed Master Mechanic of the New York, Providence & Boston Railroad (now a part of the N. Y. N. H. & H. R. R.), and when the Providence & Worcester Railroad was absorbed by the N. Y. P. & B. R. R. his jurisdiction extended over all the territory operated by the N. Y. P. & B. R. R. He remained in that position after the road was absorbed by the N. Y. N. H. & H. R. R. and up to September 15, 1904, when he resigned.

F. T. HYNDMAN.

GEORGE W. CUSHING

Was born in Portland, Maine, in 1833. He graduated from the Union Locomotive Works, Boston, Massachusetts. Since entering railway service he served from 1861 to 1869 as Master Mechanic of the Wisconsin and Milwaukee Division, Chicago & North-Western Railway; 1870 to 1871, Superintendent of Motive Power, Kansas Pacific Railway; 1871 to 1873, Superintendent Motive Power, Northern Pacific Railway, which was just then organized; 1873 to 1874, Superintendent Motive Power, Wabash & Western Railway. He afterward became Superintendent of Motive Power of the Denver & Rio Grande, and was for a time General Superintendent of that line. In 1881 he returned to the Northern Pacific as Superintendent of Motive Power and Rolling Stock. In 1887 he became Superintendent of Motive Power of the Reading Railway. He afterward was Superintendent of Motive Power of the Union Pacific, which was the last railroad position he held. He retired in 1892 from active service. Since then he has acted as representative of one of the prominent railway supply companies, his home being at Evanston, Illinois. He became a member of the Master Mechanics' Association in 1872.

Shortly before his death he disposed of his property in and about Chicago, with the view of moving to Pasadena, California, where he proposed to locate during his remaining life, and while preparing to make this move he died in Chicago.

Mr. Cushing was of the old school of Master Mechanics, master of his profession, unassuming, rather reserved, but was always a genial and sociable acquaintance.

JACOB JOHANN.

FRANK N. RISTEEN.

Frank N. Risteen died at his home in Topeka, Kansas, March 26, 1906.

Mr. Risteen was born in the Province of New Brunswick, Canada, May 24, 1856. He served as a machinist apprentice two and a half years in New Brunswick; was locomotive fireman three years; engaged in construction work on Canadian Pacific Railroad two years; was locomotive engineer on same road four years; engineer on the Northern Pacific Railroad from 1883 to 1888; road foreman of engines of the last-named road, 1888 to 1895; Master Mechanic Northern Pacific Railway at Fargo, North Dakota, 1895 to October, 1901; Assistant Superintendent of Motive Power Chicago Great Western Railway until February 1, 1902, and Mechanical Superintendent of the Eastern Grand Division of the A. T. & S. F. Ry. from that time until his death.

He became a member of the American Railway Master Mechanics' Association in 1899.

Mr. Risteen's continuous railroad experience especially fitted him for the positions which he so successfully filled in the later years of his life. He possessed a character of unusual qualities; full of manliness and integrity, which, coupled with his very genial temperament, made him a leader of men and endeared him to all with whom he associated, either in business or in social life. He leaves many friends who feel glad to have known him and sorry that he should have been taken away in the prime of life.

ALFRED LOVELL.

JOHN M. DAVIES.

John M. Davies was born in Staffordshire, England, December 6, 1835, and died in Plattsburgh, New York, March 9, 1905.

At the age of six years his father and mother immigrated to the United States and settled in Baltimore, Maryland. At an early age he became a machinist's apprentice in Danville, Pennsylvania, completing his apprenticeship about three years later. Soon afterward he accepted a position as machinist with The Glendon Iron Works at Easton, Pennsylvania, a position he held until the year 1851, when he entered the shops of the D. L. & W. R. R. Co. at Scranton, Pennsylvania, where his ability as a workman and his qualifications for managing details were soon recognized, and through successive steps he became gang foreman and machine foreman. In this capacity he remained until the year 1854, when he resigned to accept the position of locomotive engineer on the D. L. & W. R. R., where he remained for fifteen years. Terminating his connection with the railroad, he assumed charge of the delivery of locomotives for the Dickson Manufacturing Company of Scranton, Pennsylvania. In this capacity he visited most of the cities of the United States and South America. Naturally he had many unusual experiences in his travels, and one of his pleasures was to relate them to his friends.

In 1873 he resigned this position to become Master Mechanic of the Crown Point Iron Company, at Crown Point, New York. After eight years of faithful service, with acquired knowledge and recognized ability as a mechanic, he resigned to accept the position of General Superintendent of the Chateaugay Ore & Iron Company, with headquarters at Lyon Mountain, New York, where he remained until the year 1895, when he resigned and retired to private life, making his home in Plattsburgh.

Mr. Davis was a man of strong individuality and of an attractive personality. Imbued with a firm conviction as to "what is right, as we are given to understand it," his life was one of unswerving rectitude, and both in public and private life was above reproach. Possessed of a natural

faculty for enlisting the good will and winning the admiration of all with whom he came in contact, he presented the highest type of humanity, and was an honor to mankind. In the several offices he occupied his name is treasured in kind remembrance by all, and the cheery smile, the friendly greeting, the kind reproof and the manly man will not be forgotten.

Mr. Davies was married to Elizabeth Burnish at Scranton, Pennsylvania, September 9, 1854, and they celebrated their golden wedding anniversary September 9, 1904. There are left him surviving to mourn his loss besides the widow, five children, namely: Mrs. Sylvanus Taylor and John M. Davies, Jr., of this city; Frank Davies, of Standish, New York; Harry B. and Alvin R. Davies, of Schenectady, New York.

Mr. Davies was for thirty-five years a member of Union Lodge, No. 291, F. & A. M., of Scranton, Pennsylvania, and full honors of Clinton Lodge, F. & A. M., of this city, were extended at his burial. He was also an active member of the American Railway Master Mechanics' Association, his membership dating from 1890.

Jos. W. Taylor.

ANTOINE SAUTER.

Mr. Antoine Sauter died April 16, 1905, at the German Hospital, in Philadelphia, of heart failure.

Mr. Sauter was born May 4, 1848, at Mulhouse, Alsace, France, of French parentage. He was educated in the public schools, which he attended for eight years, and also had two years' schooling in a private school at Mulhouse.

He served his apprenticeship in the Kocklin Machine Shops at Mulhouse, from 1863 to 1867, at which place he worked as a journeyman for five years.

He arrived in America, April 1, 1872, and went into the service of the Erie Railway Company in the Jersey City shops, remaining there until the shops were destroyed by fire, when he was transferred to the Susquehanna shops of the same company, and worked there for ten years.

He came to Roanoke, Virginia, in the employ of the Norfolk & Western Railroad Company, July 4, 1882, where he stayed for thirteen years, being foreman of the machine shop. From this place he was transferred to Lambert's Point, Virginia, and made general foreman of the Norfolk & Western Railroad Company's shop at that point, remaining there eight years. He was then transferred to the new shops of the company at Portsmouth, Ohio, as general foreman, having charge of the installation of the plant at that place.

He remained at his work only about one year at Portsmouth, Ohio, when he was taken seriously ill, and his health was permanently impaired. On account of his impaired health, he was transferred from this shop

back to Roanoke again, where he remained for about one year, when his service with the Norfolk & Western Railway Company was terminated by his death.

Mr. Sauter became a member of the American Railway Master Mechanics' Association in 1896.

Mr. Sauter, as a man, was courteous and of sterling integrity. As a mechanic, he was skilful and painstaking. He enjoyed the confidence of his superiors and the entire respect of those who worked with him. His death was a loss to the company with which he remained so many years, as well as to his family and many friends.

JOHN A. PILCHER.

JOHN TAYLOR.

Mr. John Taylor died at his home in Minneapolis, Minnesota, on February 13, 1905, at the age of seventy-two.

Left fatherless in early childhood at his birthplace, Carronshore, Stirlingshire, Scotland, he followed his only brother, William Taylor, to this country in 1850, and became an apprentice under him, who was then Master Mechanic in the employ of the Saratoga and Washington shops (now a part of the Delaware & Hudson Canal system).

He afterwards was associated with the New York Central, the Schenectady Locomotive Works, North-Western Ry., Michigan Southern Ry. and Northern Indiana Ry. in succession. In 1859 he took charge of the latter's shop in Chicago and remained there six years.

During the Civil War he was appointed by the United States Government as general foreman of the railroad shops at Newbern, North Carolina, from whence General Sherman's army was supplied.

In 1866 he accepted the position of Master Mechanic of the Western Union railroad shops located at Racine, Wis. (which railroad was absorbed later by the Chicago, Milwaukee & St. Paul Ry.), and held the position with great satisfaction to all concerned until the shops were discontinued, when he was transferred to the much larger territory and shops at Minneapolis, Minn. Here his jurisdiction covered nearly 3,000 miles of road, with about 250 engines and about 2,000 men directly under his charge.

Through his sterling qualities of justice, tact and love for his fellows, he became one of the best known and most highly esteemed railroad men in the employ of the great system.

He was in poor health for something more than two years prior to his death, but continued to fill his position until about one year before he died.

He had been a member of the Railway Master Mechanics' Association for a great many years.

He left to mourn his loss a wife, two sons and two daughters, and a

large circle of friends, who looked upon him with love and admiration for his strong sense of justice, his loyalty and earnest efforts to the company he served and for his manly qualities as a man, a neighbor, a friend and an officer of the railroad.

WILLIAM P. APPLEYARD.

William P. Appleyard was born March 17, 1857, in Canandaigua, New York, and completed his education at Notre Dame University. He was an architect by profession, and practiced in Lansing, Michigan. In 1890 he began his railroad career by entering the employ of the Pullman Company as Mechanical Inspector, remaining in the employ of the Pullman Company for nearly three years.

In November, 1893, Mr. Appleyard went to the New York, New Haven & Hartford Railroad Company as Assistant to the Superintendent of the Car Department, being located at Boston, where he remained until the summer of 1895, when he was appointed Master Car Builder of the New Haven road, with office at New Haven, Conn. This position he held until February 1, 1904, when he resigned to re-enter the employ of the Pullman Company as Superintendent of Equipment. During Mr. Appleyard's connection with the New Haven road the parlor and sleeping car equipment was generally remodeled and brought up to the Pullman standard of excellence. Another important feature in connection with the New Haven road was the planning of the car shops at Readville, Mass. Mr. Appleyard also invented the copper-sheathed passenger car and put cars into service while on the New Haven road.

Mr. Appleyard was prominent in railway club and Master Car Builders' Association matters, having served as president of the New England Railroad Club, and being President of the Master Car Builders' Association at the time of his death. He was called on frequently for committee work in connection with the Master Car Builders' Association, and always willingly responded.

Death came suddenly to Mr. Appleyard on September 19, 1905, at Chicago, Illinois, when he was struck by a train and instantly killed. No better tribute to him can be given than that in the closing paragraph of our President's address at Atlantic City, on June 14, 1906: "We who knew him will ever feel that by his untimely death we lost a good friend, and can sympathize with his widow."

A. E. BENSON.

ALBERT J. PITKIN.

In the death of Albert J. Pitkin, president of the American Locomotive Company, the Master Mechanics' Association loses one of its most valued members, and it is especially fitting that this journal should contain a statement of his life and work.

Mr. Pitkin was born at Northampton, Ohio, March 22, 1854, and died at his home, 194 Riverside Drive, New York, on November 16, 1905. He descended from New England Puritan stock, his father being a Presbyterian minister. His mother died before he was nine years old, and he worked his way up with few friends and little help, except that of the fine spirit and traditions left him by his father and mother.

He learned the machinist's trade as an apprentice in the stationary engine works of the Webster, Camp & Lane Machine Co., Akron, Ohio, and then spent one year in the locomotive repair shops of the Cleveland, Akron & Columbus Railway.

He then went into the drawing office of the Baldwin Locomotive Works, serving under Mr. William P. Henszey, and was a fellow draftsman with Mr. William L. Austin, one of the present members of the Baldwin firm. Mr. Pitkin became, afterward, perhaps the keenest competitor of the Baldwin Company, but the mutual respect and kindly feeling, begun in his work with them, remained through his life.

In 1880 he became mechanical engineer of the Rhode Island Locomotive Works, where he enlarged his experience in locomotive design and construction.

In 1882 he accepted the position of mechanical engineer of the Schenectady Locomotive Works, and most of the remainder of his life was devoted to the development of that company. At Schenectady his vigorous personality immediately asserted itself, and he quickly proved his fitness for the position of mechanical head of the works, becoming superintendent at the age of thirty years. He served under three brothers of the Ellis family, who became successively president of the Schenectady company, and these men all recognized Mr. Pitkin's ability and character, and gave him their complete confidence and he gave them perfect loyalty, devoting all his efforts and energy to their interests. Mr. Pitkin developed the engineering and manufacturing departments of the Schenectady works to a high degree, and made unceasing efforts to cultivate high business ideals among the men in his organization. Upon the death of Edward Ellis, president of the Schenectady company, Mr. Pitkin was made vice-president and general manager, and took charge of the sales and commercial management of the business, in addition to his previous work.

He did not allow his business cares to prevent him from doing his full duty as a citizen of Schenectady, and every worthy cause found in him ready sympathy and help. A New York business man inquired of a

Schenectady resident about Mr. Pitkin's standing there. The answer, "You are asking about our first citizen," voiced the general opinion of his fellow men in that community.

At the formation of the American Locomotive Company in 1901, Mr. Pitkin became the first vice-president under Mr. S. R. Callaway, and their business association quickly developed into warm friendship, which grew stronger until Mr. Callaway's death. Mr. Pitkin brought to the American Locomotive Company a splendid experience in locomotive-building in all its branches, and the success of the company has been largely due to the confidence which railroad men felt in his ability and character, and to the loyalty and spirit of coöperation which he inspired in his organization.

At Mr. Callaway's death, Mr. Pitkin succeeded him as president of the American Locomotive Company. His working life had, however, been too absorbing and too anxious, and a short vacation which he took came too late. He did not know that the end was near, and in his last illness continued plans for his work and spoke of his love for the locomotive business.

Mr. Pitkin was primarily a locomotive designer, and never lost his interest in that department. His constant effort was to increase boiler capacity, by saving weight as far as possible in other directions, and his work in this line has not been surpassed. He was one of the first advocates of large grates, and persistently urged the use of wide fire boxes on top of the frames, in the face of strong opposition. He was one of the earliest advocates of the two-cylinder compound locomotive, and designed and built the first successful American engine of this type. He had great faith in the Mallet compound, and expected to see this design used extensively, not only for mountain service, but for regular heavy freight work. He was urgent in requiring care in the working out of details of design, and he had a keen sense of harmony in outline and artistic finish.

In planning shop extensions and improvements, he was bold and far-seeing. At the beginning of his term as superintendent, the capacity of the Schenectady plant was about 185 light locomotives per year, and the last work required to reach a capacity of 1,000 heavy locomotives per year is being completed according to his plans.

James McNaughton, general superintendent of the Schenectady works, says: "I always admired Mr. Pitkin's nerve in making improvements." It is interesting to note that the results never failed to justify the large expenditures which he made.

He constantly aimed at the best quality of work, and would accept no excuse for careless design or construction. He always wanted to give the railroads more than their specifications required, and looked with suspicion upon well-intended suggestions from his subordinates proposing to cheapen design.

His treatment of the railroad men with whom he came in contact was inspiring to those under him. He made friends because he saw the best

in men, and manifested the friendship and confidence in them which he felt.

It was once said of him that he did not know how to do business in any but a straightforward way. This was true; he did not know, and never made any attempt to learn.

He was extremely energetic and quick-tempered, but he never cherished resentment, and was quick to acknowledge mistakes. He was too energetic and too anxious about his work. It would have been better if he had taken less thought for the morrow. As it was, he died, worn out, at the age of fifty-one, but he had fought a good fight; he had helped many directly and inspired many others by his example. He rendered great service to the transportation interests of this country. He was one of the great leaders in the development of the modern American locomotive and in the upbuilding of American industry.

His life was an example of upright, conscientious, honorable manhood.

J. E. SAGUE.

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